Northeastern University
College of Engineering

COVID-19 Simulation

Final Report

Course #: INFO6205
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Project Introduction

There have been breakthroughs in understanding COVID-19, such as how soon an exposed person will develop symptoms and how many people on average will contract the disease after contact with an exposed individual. The wider research community is actively working on accurately predicting the percent population who are exposed, recovered, or have built immunity. Researchers currently build epidemiology models and simulators using available data from agencies and institutions, as well as historical data from similar diseases such as influenza, SARS, and MERS.

So, we also conduct this project and try to simulate the spread of Covid-19 virus and SARS. Through the mathematical modeling of the spread of infectious diseases, we analyze the spread speed, spatial range, transmission route and kinetic mechanism of infectious diseases, in order to guide the effective prevention and control of infectious diseases.

Project Goals

Using mathematical model to simulate the spread of Covid-19 virus and SARS.
Compare the characteristics of COVID-19 and SARS, such as fatality rate, transmission rate, recovery rate, etc. Providing relatively accurate data to guide the effective prevention and control those viruses.

Project Detail

- **Implementation**

In this project, there are four packages in total. They are COVID19, SARS, Helper and UserInterface. Package COVID19 and package SARS are the main body of the simulation, and they both follow the same logic. The only difference between them is the virus's variables which are defined in Variables class of Helper package.

In both virus package, they all have three classes, namely Person, City and JPanel. First, the City class describes an ideal city located in a certain location (x, y). And, the City has some amount of citizen who lives in the City. The citizens are a certain number of Person stored in Array List.

```java
public class City1 {
    private CityLocation location;
    private Person1 person1;
    private List<Person1> person1List = new ArrayList<Person1>();

    private static City1 city1 = new City1();
    public static City1 getInstance() {
        return city1;
    }
    public List<Person1> getPersonList() {
        return person1List;
    }
```

The Person class illustrates one person. Each person would have one random initial location (x, y) within the City and can move around the city just like what we are doing in our daily lives.

- How to generate the person's initial random location:

```java
/*
 * b*random.nextGaussian()+a
 * Generate a point(a,b) which follows normal distribution
 * Standard deviation: 150, mean: city location
 */
int x = (int) (150 * random.nextGaussian() + location.getOriginX());
int y = (int) ((150 * random.nextGaussian()) + location.getOriginY());
if (x > Variables.City_Width) {
    x = Variables.City_Width;
}
if (y > Variables.City_Height) {
    y = Variables.City_Height;
}
person1 = new Person1( x, y);
person1List.add(person1);
```

Normally, people would live around city. Thus, we assume that the person's location follows the normal distribution with the mean of the city's location and a certain standard deviation (We assume that the standard deviation of this case is 150 unit). Therefore, we use Java's inner class Random to generate the random Gaussian ("normally") distributed double value with mean 0.0 and standard deviation 1.0 from this random number generator's sequence. Then use the formular to transfer this value to the location we want.

- How to make the person move around the city:

First, we must know whether the person wants to stay at home or move around. If they want to stay at home, then they do not need to move.

```java
/**
 * The person moves around the city
 */
public void moveAroundCity(){
    if (probability.stayAtHome()){
        return;//stay at home
    }
```

Per the desk research, there is only 15% people would stay at home in normal days. After stay-at-home order released, the number jumps to 99%. Here we assume that the single person's stay at home probability is the same as the total probability. And in the Probability

Generator class of the Helper package, we use the Random class to generate a certain probability. For the instance of stay-at-home probability, we generate an integer ranging from 1 (inclusive) to 100 (inclusive). The probability of getting an integer less than 15 is 15%. When the random integer is less than the stay-at-home probability, we set the return Boolean value is true, or it is false. Then, we will have a function stayAtHome() which has the exact same probability with the stay-at-home probability to be true. If stayAtHome() returns true, which means the person wants to stay at home, then the person will not move.

```
public boolean stayAtHome(){
    boolean result = false;
    if (random.nextInt(100) + 1 <= Variables.StayAtHome_Rate){
        result = true;//probability to stay at home
    }
    return result;
}
```

After judging the person's probability of stay-at-home, then we should know if the person has already arrived at the target. Here we assume that if the distance between the person's current location and the target location is less than 1, the person will be considered arrived. If arrived, the system is going to generate a new move target location, otherwise the person is going to move to the previous target until arrives. We use the same method of getting the person's initial location to generate the person's random move target.

```
//generate new moveTarget if the moveTarget is null or already arrived
if (moveTarget==null || moveTarget.isArrived()){

    /* use normal distribution to generate the target point with the mean=(x,y),
    *standard deviation = 150
    */
    int targetx = (int)(150 * random.nextGaussian() + x);
    int targety = (int)(150 * random.nextGaussian() + y);
    moveTarget = new MoveTarget(targetx,targety);

    //if the move target is out of city, set the target at the city boundary
    if (moveTarget.getX() > Variables.City_Width){
        moveTarget.setX(Variables.City_Width);
    }
    if (moveTarget.getY() > Variables.City_Height){
        moveTarget.setY(Variables.City_Height);
    }
}else {
//calculate the distance to the target point
    double targetDistance = Math.sqrt(Math.pow(moveTarget.getX()-x, 2) + Math.pow(moveTarget.getY()-y, 2));
    if (targetDistance <= 1 ) {
        moveTarget.setArrived();
        return;
    }
}
```

After finishing all the prerequisite judgments, the person should move to the target with a certain direction. The person's moving direction is determined by the person's current location and the move target's location. If the target's x coordinate is greater than the person's x coordinate, the person moves 1 unit to the right direction, otherwise moves the same unit to the left. Similarly, if the target's y coordinate is greater than the person's y coordinate, the person moves 1 unit up, otherwise moves the same unit down. If the person arrives at the boundary of the city, the person will turn around.

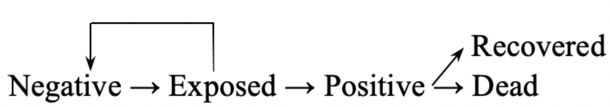
```java
//move to the target
int ox;//direction on x axis
int oy;//direction on y axis

int dx = moveTarget.getX() - x;
int dy = moveTarget.getY() - y;

if (dx >= 0){//target point is on the right of the person
    ox = 1;
}else{
    ox = -1;
}

if (dy >= 0){//target point is upper of the person
    oy = 1;
}else{
    oy =-1;
}

//Movement boundary on x axis
if (getX() > Variables.City_Width || getX() < 0) {
    moveTarget = null;
    ox = -1;
}
//Movement boundary on x axis
if (getY() > Variables.City_Height || getY() < 0) {
    moveTarget = null;
    oy = 1;
}

// update this person's position
x += ux *ox;
y += uy *oy;
```

- How to change the person's status:

  Along with the basic movement of the person, the status should be changed accordingly. There are five different statuses for one person. They are Negative, Exposed, Positive, Dead and Recovered. Plus, each person has one initial status as Negative.

```java
/**
 * A person's different Status
 */
public enum Status{
    Negative("Negative"),
    Exposed("Exposed"),
    Positive("Positive"),
    Dead("Dead"),
    Recovered("Recovered");

    private final String value;
    Status(String value){
        this.value = value;
    }

    @Override
    public String toString() {
        return value;
    }

}
```

Here are how these statuses develop:



The Negative means the person is tested negative to the virus. The Exposed means the person stays too close to or closely contacts with someone infected, which does not mean the person is already positive but means the person has certain chance to go Positive or go Negative. Exposed status means the person is in the incubation period. If unfortunately, the person is Positive, there is still a chance to turn to Recovered. If not, then the person's status turns to Dead.

During the development of the statuses, several variables of the virus are used to determine the turning point of a status change.

a) For the Dead person, there is no extra actions.

```
public void updateStatus(){

    //Deal with Dead person
    if (status.equals(Status.Dead.toString())){
        return;
    }
```

b) For the Exposed person, they are contagious as well. If a Negative person stays too close to the Exposed person then, the Negative person would be Exposed. Because all the contagious viruses have the R factor which means the average number of secondary infections produced by a single infected person. If the Exposed person has already infected maximum number of people, then the Exposed person will stop infect other people.

```
//Deal with Exposed person
if (status.equals(Status.Exposed.toString())) {
    //To find people around the person within the Safe_Distance
    for (Person1 person1 : City1.getInstance().getPersonList()) {
        if (distance(person1) < Variables.Safe_Distance){
            if (person1.getStatus().equals(Status.Negative.toString())) {
                person1.getExposed();
                infectedPersonNum++;
                //Max people one infected person can infect
                if (infectedPersonNum == Variables.R_Factor){
                    break;
                }
            }
        }
    }
```

Next, the system would pick up a random time based on the average incubation time by using the normal distribution to generate a random Positive time with a certain mean and a standard deviation. If the time comes to this random time, we will use the infected probability to determine if this Exposed person would go Positive or not. The infected probability follows the same method of generating stay-at-home probability. If the

Exposed person does not turn to Positive at the random time, then will turn to Negative when exposed time is longer than the virus incubation period.

```
/*Pick up a random time to turn Positive based on the Average_Incubation_Time
  use normal distribution to generate a random Dead time with mean = 5 days, standard deviation = 2 day
*/
double certainTime = Variables.Average_Incubation_Period + random.nextGaussian()*2;
if (COVID19JPanel.dayTime - ExposedTime > certainTime && status.equals(Status.Exposed.toString()) ){
    if (probability.Infected_COVID19()){
    getPositive();
    }
}

//turn to Negative if ExposedTime > 14 days
if (COVID19JPanel.dayTime - ExposedTime >= Variables.Incubation_Period && status.equals(Status.Exposed.toString())){
    setStatus(Status.Negative.toString());
}
}
```

c) For the Positive person, it has the same logic with Exposed person to infect a certain amount people and turn to Recovered or Dead.

```
//Deal with Positive person
if (status.equals(Status.Positive.toString())) {
    //To find people around the person within the Safe_Distance
    for (Person1 person1 : City1.getInstance().getPersonList()) {
        if (distance(person1) < Variables.Safe_Distance){
            if (person1.getStatus().equals(Status.Negative.toString())) {
                person1.getExposed();
                infectedPersonNum++;
                //Max people on infected person can infect
                if (infectedPersonNum == Variables.R_Factor){
                    break;
                }
            }
        }
    }

    //Positive person has a certain probability to die everyday based on the Case_Fatality ratio
    if (probability.Dead_COVID19()) {
        setStatus(Status.Dead.toString());
    }

    /*Pick up a random time to turn Dead
     *use normal distribution to generate a random Dead time with mean = 19 days, standard deviation = 5 day
    */
    double certainTime = Variables.Average_Days_Death + random.nextGaussian()*5;
    if (COVID19JPanel.dayTime - PositiveTime > certainTime && status.equals(Status.Positive.toString()) ){
            setStatus(Status.Dead.toString());
    }

    //turn to Recovered if Positive time is greater the Recovery Time
    if (COVID19JPanel.dayTime -PositiveTime >= probability.RecoveryTime_COVID19() && status.equals(Status.Positive.toString())) {
        setStatus(Status.Recovered.toString());
    }
}
```

After finishing the status update, the person would move once. So far, the person has finished one total action for once. With the JPanel thread going on, the person will repeat the action again and again.

Besides, the function implements of the person class. The judgments of the action are very vital. These variables determine the probability of infected, dead, and recovered. And some of these variables may be changed under different conditions. We set three basic conditions, whether to wear a mask, whether to quarantine(stay at home), whether the government acts(the prevalence of testing and contact tracing). By changing these three conditions, the virus would spread differently from that without any intervention actions.

Here are COVID19 variables:

```
/**
 * COVID19
 */

/*
 *  The rate of people get infected in USA: 4.5%
 *  Calculated by Confirmed_Cases_in_USA/Total_population_in_USA
 */
public static int Infection_Rate = GovernmentAction? 2 : 5;
/**
 * Average number of of secondary infections produced by a single infected person
 * https://www.gov.uk/guidance/the-r-number-in-the-uk#latest-r-number-and-growth-rate
 * https://www.bbc.com/news/health-52903787
 * https://med.sina.cn/article_detail_103_1_82609.html
 *
 * COVID19 and SARS have the same R factor
 */
public static int R_Factor = Quarantine ? 1:3;


/*
 * The percentage of different severity of symptomatic infection
 * https://www.uptodate.com/contents/coronavirus-disease-2019-covid-19-clinical-features
 *
 * Different severity has different recover time
 */
public static int Mild_Disease_Severity = 81;//Severe:0.14;Critical:0.05

public static int Mild_Recovery_Time = 140;// 2 weeks, 10 = 1 day
public static int Severe_Recovery_Time = 420;// 6 weeks, 10 = 1 day


/*
 * Case Fatality Ratio
 * the number of deaths divided by the number of confirmed cases
 * https://coronavirus.jhu.edu/data/mortality
 */
public static int Case_Fatality= 2;
public static int Average_Days_Death = 190;//190 = 19 days

public static int Incubation_Period = 140;// 140 = 14 days
public static int Average_Incubation_Period = 50;// 50 = 5 days
public static float Safe_Distance = WearMask ? 3f : 6f; //1f=2 feet
```

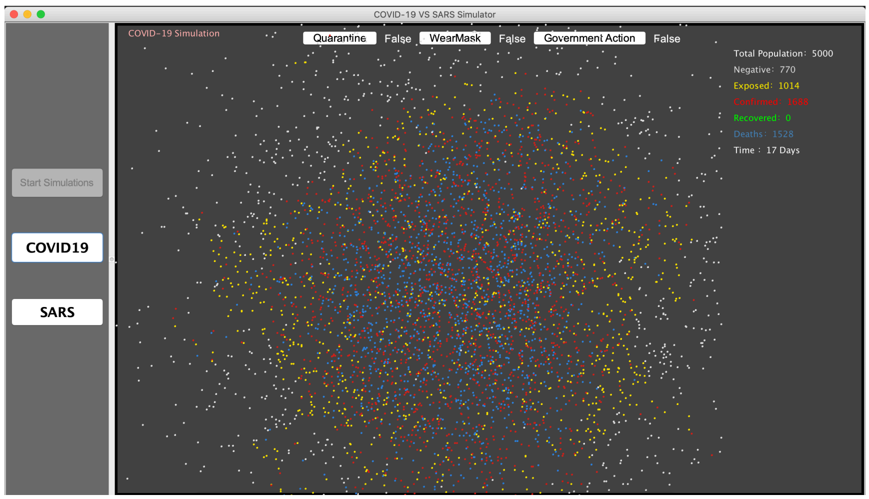
Here are SARS variables:

```
/**
 * SARS
 * https://www.nhs.uk/conditions/sars/
 * https://www.hopkinsmedicine.org/health/conditions-and-diseases/severe-acute-respiratory-syndrome-sars
 * https://www.cidrap.umn.edu/news-perspective/2003/05/estimates-sars-death-rates-revised-upward
 * https://www.who.int/csr/sars/en/WHOconsensus.pdf
 */
public static float Infection_Rate2 = GovernmentAction? 0.5f : 1f;
public static int Mild_Disease_Severity2 = 75;//Severe:25%

public static int Mild_Recovery_Time2 = 100;// 100 = 10 day
public static int Severe_Recovery_Time2 =  420;// 420 = 42 days


public static int Case_Fatality2= 10;
public static int Average_Days_Death2 = 200;//200 = 20 days

public static int Incubation_Period2 = 100;// 100 = 10 days
public static int Average_Incubation_Period2 = 60;// 60 = 6 days
public static float Safe_Distance2 = WearMask ? 1f : 3f; //1f=2 feet
```

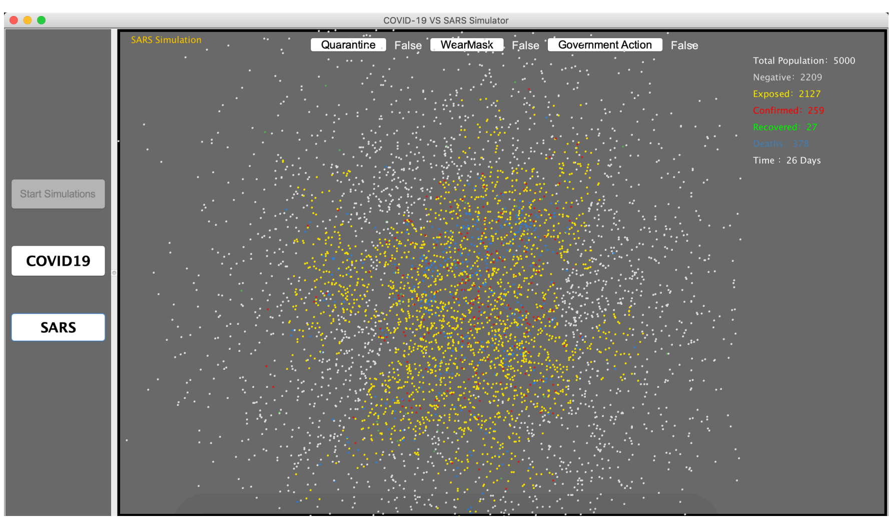
- ## Output and analysis

In our program, we set up a city which width is 900 and length is 800. There are 5000 people in this city. Graph1 and Graph 2 is the user interface of our simulation program. The white point is the Negative person. The yellow point is the exposed and incubated person. The red point is infectious person. The green point is the person who has recovered. The blue point is the death person.

In this project, we compare two four-level viruses, they are the COVID-19 and SARS.
We set the origin Exposed people number as 50.



Graph1 Simulation Interface



Graph2 Simulation Interface

COVID-19

Before

```java
public static boolean WearMask = false;
public static boolean Quarantine = false;
public static boolean GovernmentAction = false; //The prevalence of testing and contact tracing;
```

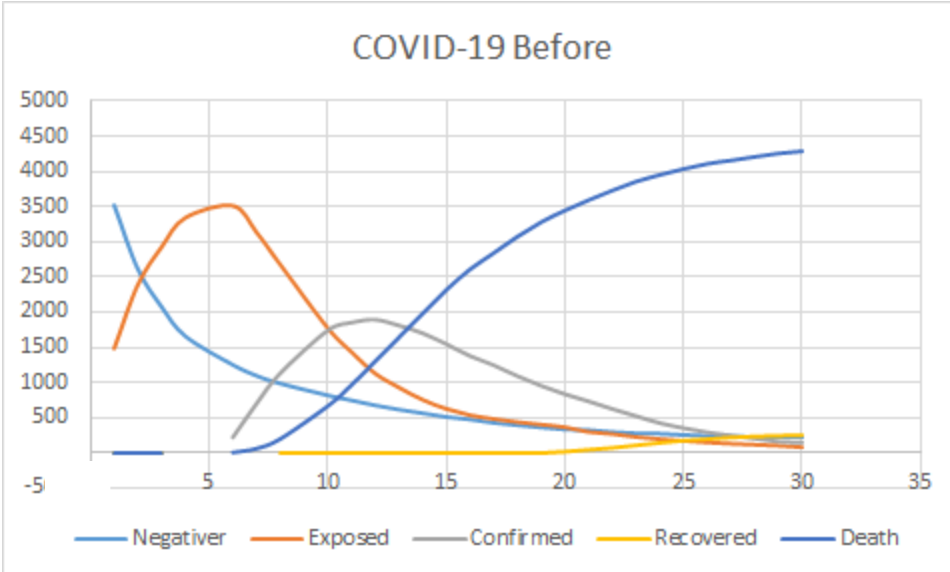
That means people do not wear face masks to protect themselves and they are easy to be infected. And the government does not isolate the crowd, and there is currently no quarantine in the city.

With time passing by, the exposed population peak, then reach an inflection point as the exposed becomes infected, and as treatment and autoimmunity reduce the number of exposed and infections and increase the number of death people. Around day 14, the infected population reach the largest number, which is about 1700 people. At about day 19, the city began to have recovered people, and gradually grow over time.

```
------COVID19_Sim DAY 1 ------
Negative number: 3523
Exposed number: 1477
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 2 ------
Negative number: 2613
Exposed number: 2387
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 3 ------
Negative number: 2077
Exposed number: 2923
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 4 ------
Negative number: 1660
Exposed number: 3340
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 6 ------
Negative number: 1254
Exposed number: 3511
Confirmed number: 224
Recovered number: 0
Death number: 11
```

```
------COVID19_Sim DAY 11 ----
Negative number: 749
Exposed number: 1427
Confirmed number: 1854
Recovered number: 0
Death number: 970
------COVID19_Sim DAY 12 ----
Negative number: 678
Exposed number: 1121
Confirmed number: 1894
Recovered number: 0
Death number: 1307
------COVID19_Sim DAY 13 ----
Negative number: 617
Exposed number: 922
Confirmed number: 1813
Recovered number: 0
Death number: 1648
------COVID19_Sim DAY 14 ----
Negative number: 565
Exposed number: 746
Confirmed number: 1703
Recovered number: 0
Death number: 1986
------COVID19_Sim DAY 14 ----
Negative number: 564
Exposed number: 735
Confirmed number: 1680
Recovered number: 0
Death number: 2021
```

```
------COVID19_Sim DAY 26 ----
Negative number: 242
Exposed number: 138
Confirmed number: 297
Recovered number: 205
Death number: 4118
------COVID19_Sim DAY 27 ----
Negative number: 238
Exposed number: 119
Confirmed number: 250
Recovered number: 228
Death number: 4165
------COVID19_Sim DAY 28 ----
Negative number: 226
Exposed number: 105
Confirmed number: 209
Recovered number: 243
Death number: 4217
------COVID19_Sim DAY 29 ----
Negative number: 226
Exposed number: 92
Confirmed number: 166
Recovered number: 252
Death number: 4264
------COVID19_Sim DAY 30 ----
Negative number: 223
Exposed number: 69
Confirmed number: 152
Recovered number: 260
Death number: 4296
```

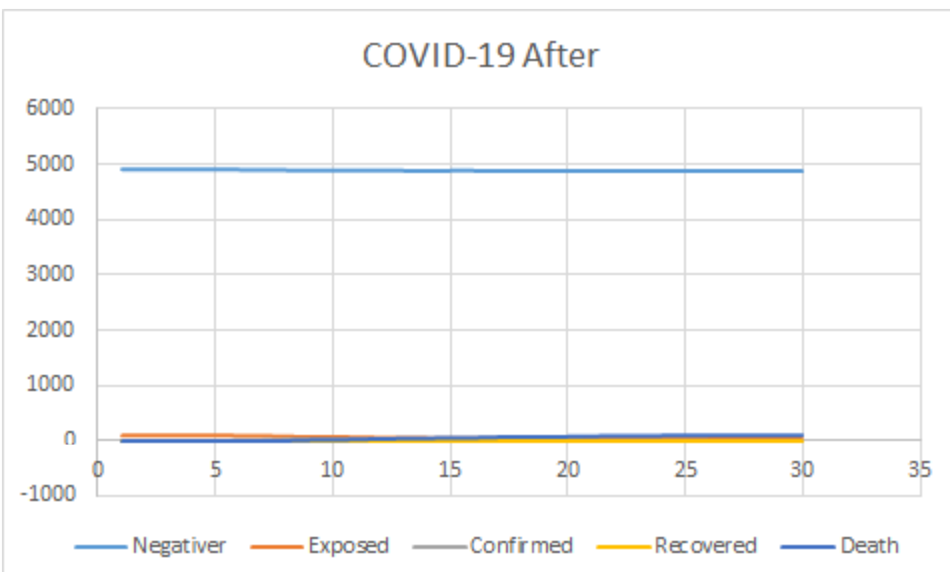


After

```
public static boolean WearMask = true;
public static boolean Quarantine = true;
public static boolean GovernmentAction = true; //The prevalence of testing and contact tracing;
```

Set these three judgment conditions all change to “true”, other variables are unchanged. In this situation, people have strengthened their protection against viruses. Obviously, compared to before, the number of Exposed people have a huge drop. The first days’ exposed person only 84 and peaked on the 11st day. Confirmed number and death number both have significant decline. Especially start from Days 23, the number of deaths barely change.

```
<terminated> MainJFrame (2) [
------COVID19_Sim DAY 1 --
Negative number: 4916
Exposed number: 84
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 2 --
Negative number: 4914
Exposed number: 86
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 3 --
Negative number: 4913
Exposed number: 87
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 4 --
Negative number: 4911
Exposed number: 89
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 5 --
Negative number: 4909
Exposed number: 91
Confirmed number: 0
Recovered number: 0
Death number: 0
------COVID19_Sim DAY 6 --
Negative number: 4908
Exposed number: 80
Confirmed number: 11
Recovered number: 0
Death number: 1
------COVID19_Sim DAY 7 --
Negative number: 4901
Exposed number: 79
Confirmed number: 16
Recovered number: 0
Death number: 4
------COVID19_Sim DAY 9 --
Negative number: 4896
Exposed number: 56
Confirmed number: 29
Recovered number: 0
Death number: 19
------COVID19_Sim DAY 10 -
Negative number: 4896
Exposed number: 48
Confirmed number: 28
Recovered number: 0
Death number: 28
------COVID19_Sim DAY 11 -
Negative number: 4892
Exposed number: 50
Confirmed number: 27
Recovered number: 0
Death number: 31
------COVID19_Sim DAY 12 -
Negative number: 4891
Exposed number: 40
Confirmed number: 29
Recovered number: 0
Death number: 40
------COVID19_Sim DAY 13 -
Negative number: 4890
Exposed number: 32
Confirmed number: 31
Recovered number: 0
Death number: 47
------COVID19_Sim DAY 14 -
Negative number: 4886
Exposed number: 32
Confirmed number: 31
Recovered number: 0
Death number: 51
------COVID19_Sim DAY 15 -
Negative number: 4890
Exposed number: 25
Confirmed number: 28
Recovered number: 0
Death number: 57
------COVID19_Sim DAY 16 -
Negative number: 4889
Exposed number: 23
Confirmed number: 27
Recovered number: 0
Death number: 61
------COVID19_Sim DAY 23
Negative number: 4881
Exposed number: 14
Confirmed number: 10
Recovered number: 0
Death number: 95
------COVID19_Sim DAY 24
Negative number: 4881
Exposed number: 14
Confirmed number: 8
Recovered number: 0
Death number: 97
------COVID19_Sim DAY 25
Negative number: 4881
Exposed number: 13
Confirmed number: 9
Recovered number: 0
Death number: 97
------COVID19_Sim DAY 26
Negative number: 4880
Exposed number: 14
Confirmed number: 7
Recovered number: 0
Death number: 99
------COVID19_Sim DAY 27
Negative number: 4880
Exposed number: 14
Confirmed number: 6
Recovered number: 0
Death number: 100
------COVID19_Sim DAY 28
Negative number: 4880
Exposed number: 13
Confirmed number: 4
Recovered number: 0
Death number: 103
------COVID19_Sim DAY 29
Negative number: 4880
Exposed number: 10
Confirmed number: 6
Recovered number: 0
Death number: 104
------COVID19_Sim DAY 30
Negative number: 4880
Exposed number: 9
Confirmed number: 6
Recovered number: 0
Death number: 105
```



SARS

Before

```java
public static boolean WearMask = false;
public static boolean Quarantine = false;
public static boolean GovernmentAction = false; //The prevalence of testing and contact tracing;
```

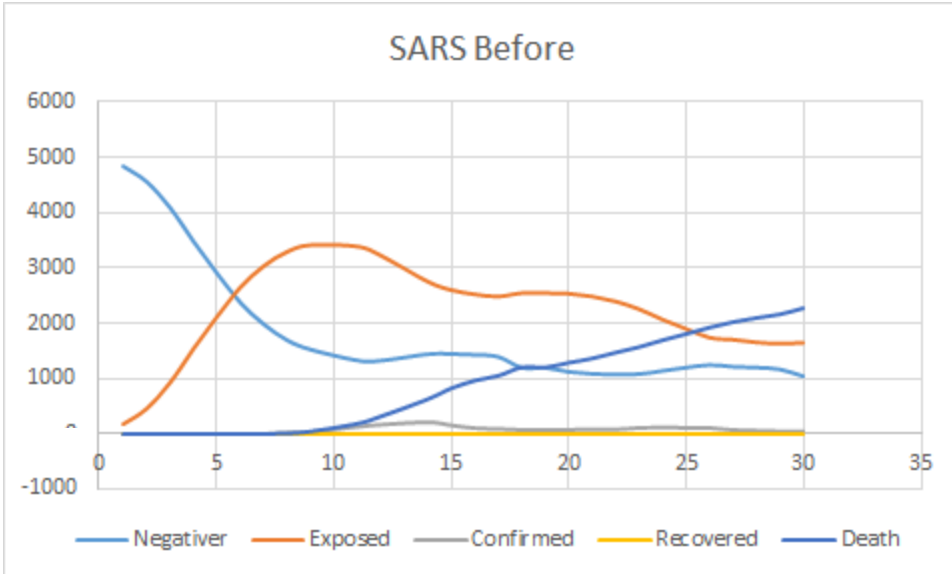
Like the previous new coronavirus, the number of people exposed to the virus has increased sharply without any protective measures. Reached the top only on the sixth day. At the same time the first death appeared on that day. Since then, the number of dead has increased dramatically over time. After 30 days, the death toll reached 2236. Interestingly, no one recovered(self-cure) in 30 days.

```
------SARS_Sim DAY 1 ------
Negative number: 4830
Exposed number: 170
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 2 ------
Negative number: 4550
Exposed number: 450
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 3 ------
Negative number: 4080
Exposed number: 920
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 4 ------
Negative number: 3470
Exposed number: 1530
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 5 ------
Negative number: 2894
Exposed number: 2106
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 6 ------
Negative number: 2365
Exposed number: 2635
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 7 ------
Negative number: 1970
Exposed number: 3021
Confirmed number: 5
Recovered number: 0
Death number: 4
```

```
------SARS_Sim DAY 8 -----
Negative number: 1682
Exposed number: 3278
Confirmed number: 25
Recovered number: 0
Death number: 15
------SARS_Sim DAY 9 -----
Negative number: 1513
Exposed number: 3396
Confirmed number: 40
Recovered number: 0
Death number: 51
------SARS_Sim DAY 11 ----
Negative number: 1316
Exposed number: 3370
Confirmed number: 121
Recovered number: 0
Death number: 193
------SARS_Sim DAY 12 ----
Negative number: 1314
Exposed number: 3206
Confirmed number: 156
Recovered number: 0
Death number: 324
------SARS_Sim DAY 14 ----
Negative number: 1431
Exposed number: 2737
Confirmed number: 195
Recovered number: 0
Death number: 637
------SARS_Sim DAY 15 ----
Negative number: 1434
Exposed number: 2586
Confirmed number: 146
Recovered number: 0
Death number: 834
------SARS_Sim DAY 16 ----
Negative number: 1419
Exposed number: 2509
Confirmed number: 100
Recovered number: 0
Death number: 972
```

```
------SARS_Sim DAY 17 --
Negative number: 1383
Exposed number: 2471
Confirmed number: 86
Recovered number: 0
Death number: 1060
------SARS_Sim DAY 19 --
Negative number: 1185
Exposed number: 2533
Confirmed number: 70
Recovered number: 0
Death number: 1212
------SARS_Sim DAY 20 --
Negative number: 1111
Exposed number: 2520
Confirmed number: 72
Recovered number: 0
Death number: 1297
------SARS_Sim DAY 21 --
Negative number: 1075
Exposed number: 2471
Confirmed number: 81
Recovered number: 0
Death number: 1373
------SARS_Sim DAY 22 --
Negative number: 1059
Exposed number: 2382
Confirmed number: 79
Recovered number: 0
Death number: 1480
------SARS_Sim DAY 23 --
Negative number: 1071
Exposed number: 2243
Confirmed number: 106
Recovered number: 0
Death number: 1580
------SARS_Sim DAY 24 --
Negative number: 1129
Exposed number: 2056
Confirmed number: 111
Recovered number: 0
Death number: 1704
```

```
------SARS_Sim DAY 24 -
Negative number: 1129
Exposed number: 2056
Confirmed number: 111
Recovered number: 0
Death number: 1704
------SARS_Sim DAY 25 -
Negative number: 1189
Exposed number: 1889
Confirmed number: 105
Recovered number: 0
Death number: 1817
------SARS_Sim DAY 26 -
Negative number: 1235
Exposed number: 1731
Confirmed number: 102
Recovered number: 0
Death number: 1932
------SARS_Sim DAY 27 -
Negative number: 1204
Exposed number: 1693
Confirmed number: 71
Recovered number: 0
Death number: 2032
------SARS_Sim DAY 28 -
Negative number: 1188
Exposed number: 1646
Confirmed number: 58
Recovered number: 0
Death number: 2108
------SARS_Sim DAY 29 -
Negative number: 1157
Exposed number: 1622
Confirmed number: 47
Recovered number: 0
Death number: 2174
------SARS_Sim DAY 30 -
Negative number: 1092
Exposed number: 1624
Confirmed number: 48
Recovered number: 0
Death number: 2236
```



After

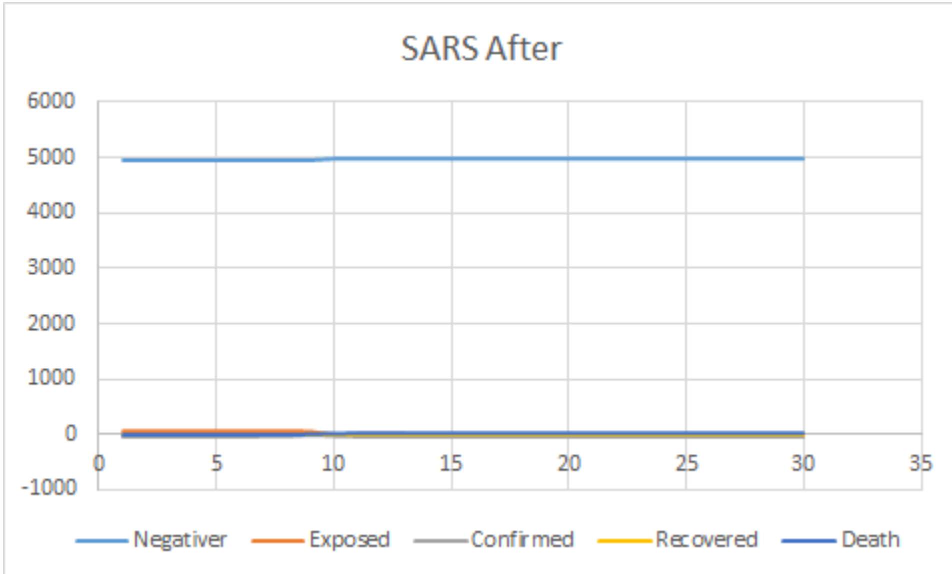
```
public static boolean WearMask = true;
public static boolean Quarantine = true;
public static boolean GovernmentAction = true; //The prevalence of testing and contact tracing;
```

Set these three judgment conditions all change to “true”, other variables are unchanged. In this situation, people have strengthened their protection against viruses. Similarly, the number of people in all indicators has dropped dramatically. And compared to the new crown, the degree of decline is several times greater. At day 6, the number of exposed people reach to top and it’s just 52. The most important thing is that the death toll was only 13 after 30 days, a 99% decrease compared to before.

```
------SARS_Sim DAY 1 ---
Negative number: 4950
Exposed number: 50
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 2 ---
Negative number: 4949
Exposed number: 51
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 3 ---
Negative number: 4949
Exposed number: 51
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 4 ---
Negative number: 4948
Exposed number: 52
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 5 ---
Negative number: 4948
Exposed number: 52
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 6 ---
Negative number: 4948
Exposed number: 52
Confirmed number: 0
Recovered number: 0
Death number: 0
------SARS_Sim DAY 7 ---
Negative number: 4948
Exposed number: 50
Confirmed number: 2
Recovered number: 0
Death number: 0
```

```
------SARS_Sim DAY 10 ------
Negative number: 4983
Exposed number: 5
Confirmed number: 3
Recovered number: 0
Death number: 9
------SARS_Sim DAY 11 ------
Negative number: 4982
Exposed number: 6
Confirmed number: 1
Recovered number: 0
Death number: 11
------SARS_Sim DAY 12 ------
Negative number: 4982
Exposed number: 6
Confirmed number: 0
Recovered number: 0
Death number: 12
------SARS_Sim DAY 13 ------
Negative number: 4982
Exposed number: 6
Confirmed number: 0
Recovered number: 0
Death number: 12
------SARS_Sim DAY 14 ------
Negative number: 4983
Exposed number: 4
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 15 ------
Negative number: 4983
Exposed number: 4
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 16 ------
Negative number: 4983
Exposed number: 4
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 17 ------
Negative number: 4983
Exposed number: 4
Confirmed number: 0
Recovered number: 0
Death number: 13
```

```
------SARS_Sim DAY 19 ------
Negative number: 4983
Exposed number: 4
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 20 ------
Negative number: 4985
Exposed number: 2
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 21 ------
Negative number: 4986
Exposed number: 1
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 22 ------
Negative number: 4987
Exposed number: 0
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 23 ------
Negative number: 4987
Exposed number: 0
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 24 ------
Negative number: 4987
Exposed number: 0
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 25 ------
Negative number: 4987
Exposed number: 0
Confirmed number: 0
Recovered number: 0
Death number: 13
------SARS_Sim DAY 26 ------
Negative number: 4987
Exposed number: 0
Confirmed number: 0
Recovered number: 0
Death number: 13
```



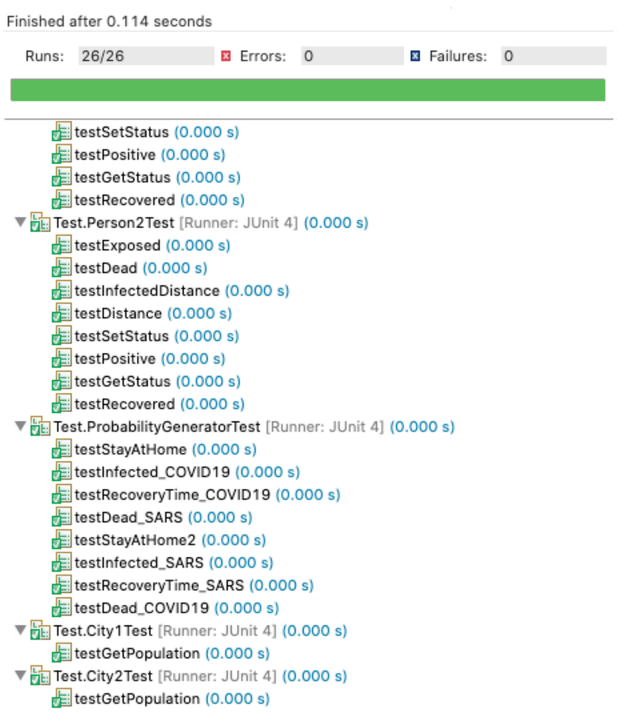
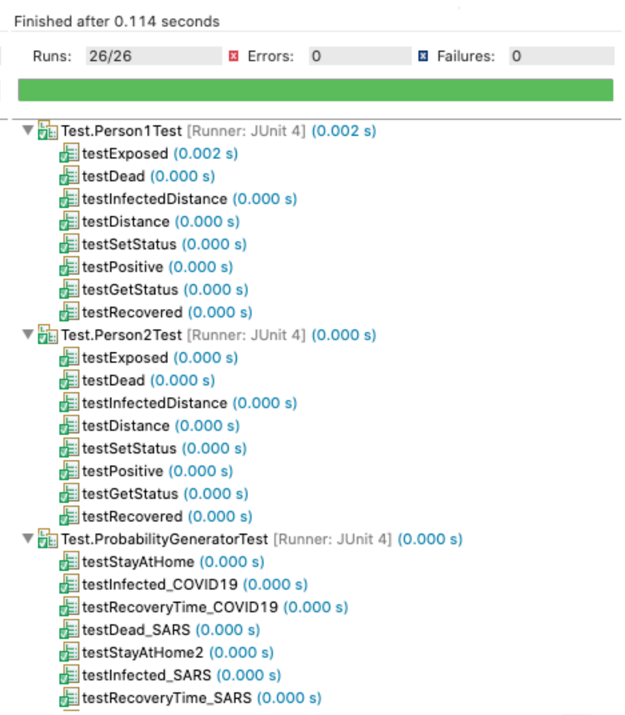
Conclusion

In this project, we simulated the spread of Covid-19 virus and SARS. After the simulation experiments, we can conclude that:

- If we keep staying at home and maintaining social distance with each other, wear face masks, or the government can take enforcement measures in time, we will effectively reduce the spread of the epidemic and the number of infected people. If we do nothing and just live as normal, finally most of the citizens would be infected.
- Covid-19 vs SARS

  Comparing the simulations of these two viruses before adding protection conditions, it is obvious that the transmission rate of the Covid-19 is higher, but the number of people who have recovered through treatment is relatively larger. Comparing the fatality rate of the two, SARS is slightly higher. After three protective measures added, it is obvious that the improvement of survival of SARS is even greater. Wearing a mask and social distancing can more effectively contain the spread of the virus.
- As we can see from this simulation, we did not conclude the medical treatment factor into account. This simulation mainly illustrates the natural status of people and virus. Even if all people stay at home, the number of recovery people is not very large due to the high mortality rate. Therefore, we still need the medical treatment to help us defeat the virus.

Unit Tests


Finished after 0.114 seconds
Runs: 26/26
Errors: 0
Failures: 0
testSetStatus (0.000 s)
testPositive (0.000 s)
testGetStatus (0.000 s)
testRecovered (0.000 s)
Test.Person2Test [Runner: JUnit 4] (0.000 s)
testExposed (0.000 s)
testDead (0.000 s)
testInfectedDistance (0.000 s)
testDistance (0.000 s)
testSetStatus (0.000 s)
testPositive (0.000 s)
testGetStatus (0.000 s)
testRecovered (0.000 s)
Test.ProbabilityGeneratorTest [Runner: JUnit 4] (0.000 s)
testStayAtHome (0.000 s)
testInfected_COVID19 (0.000 s)
testRecoveryTime_COVID19 (0.000 s)
testDead_SARS (0.000 s)
testStayAtHome2 (0.000 s)
testInfected_SARS (0.000 s)
testRecoveryTime_SARS (0.000 s)
testDead_COVID19 (0.000 s)
Test.City1Test [Runner: JUnit 4] (0.000 s)
testGetPopulation (0.000 s)
Test.City2Test [Runner: JUnit 4] (0.000 s)
testGetPopulation (0.000 s)

Finished after 0.114 seconds
Runs: 26/26
Errors: 0
Failures: 0
Test.Person1Test [Runner: JUnit 4] (0.002 s)
testExposed (0.002 s)
testDead (0.000 s)
testInfectedDistance (0.000 s)
testDistance (0.000 s)
testSetStatus (0.000 s)
testPositive (0.000 s)
testGetStatus (0.000 s)
testRecovered (0.000 s)
Test.Person2Test [Runner: JUnit 4] (0.000 s)
testExposed (0.000 s)
testDead (0.000 s)
testInfectedDistance (0.000 s)
testDistance (0.000 s)
testSetStatus (0.000 s)
testPositive (0.000 s)
testGetStatus (0.000 s)
testRecovered (0.000 s)
Test.ProbabilityGeneratorTest [Runner: JUnit 4] (0.000 s)
testStayAtHome (0.000 s)
testInfected_COVID19 (0.000 s)
testRecoveryTime_COVID19 (0.000 s)
testDead_SARS (0.000 s)
testStayAtHome2 (0.000 s)
testInfected_SARS (0.000 s)
testRecoveryTime_SARS (0.000 s)

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