

# **Program Structures & Algorithms**

**Fall 2020**

## **Team Project--Virus Simulation**

Team member: Li Taihao, Ren Junyan (section6)

### **1. Introduction:**

Our task is to simulate the spread of a virus such as SARS-CoV-2, the pathogen behind COVID-19.

You will take into account:

The k and R factors of the disease;

The population density;

The usage and effectiveness of masks;

The prevalence of testing and contact tracing;

Any barriers to entry (including quarantining) into the subject area;

Any other factors that you deem appropriate.

### **2. Aim of Task:**

This is a very open-ended project. The goal is for you to understand how to do simulations (you've already done some) and how to draw conclusions from your observations. In particular, I would like you to compare at least two viruses with different k/R factors: the most obvious one would be SARS-CoV ("SARS"). You must provide unit tests for all of your formulas, rules, etc. – your code should have at least 60% coverage by line.

### **3. Complete project details:**

In order to simulate the spread of a virus, we design this project and details as follow:

We create Interface State to define different attributes for different state of a Person.

Class Point and class Move are used to simulate one Person's location and moving.

Class MathUtil is used for generate random numbers which obey Gaussian distribution, we would use this class to simulate most random events.

Class Person is designed to simulate one person's action and update state in one unit time.

```
private float SAFE_DIST = 1.8f; //safe distance
```

Besides, we set safe distance for the virus as 1.8m equal to 6 feet in class Person.

Class Population can Initialize Population and get number of certain person in this Project.  
Class Bed,Hospital,Quarantine are used for designing locations for patients and person need quarantine. They could be clearly displayed on the GUI.

Class Graph can support GUI which can show different person and current time information.  
Class Factors include most important parameters in this project.There are the details :

```
public static float BROAD_RATE = 0.8f;//virus transmission rate
public static float SHADOW_TIME = 140;//Shadow period (1 day equals value of 10)
public static int HOSPITAL_RECEIVE_TIME = 30;//Response time
public static int BED_COUNT = 20;//Number of hospital beds
public static int Quarantine_BED_COUNT = 0;//Number of Quarantine beds
public static int Quarantine_WAIT_TIME = 30;//Quarantine waiting time
public static int R=3;// R factors,R=BROAD_RATE/CURE_RATE
public static float K=0.1f;//K factors,Which means 80% of infections are caused by K*100% of positive cases.
public static float CURE_RATE=BROAD_RATE/R;
public static float RE_INFECTED_RATE=0.2f;//
public static float BROAD_RATE_SUPER= 4*(1-K)*BROAD_RATE/K;//Super infectors Broad rate
public static int HARD_TIME= 140;//after hard time people have cure chance

/**
 * The prevalence of testing and contact tracing range: [-0.99,0.99]
 * -0.99 people will contact with low level of intention
 * 0.99 people will contact with high level of intention
 */
public static float Contact_Intention = 0.99f;
public static int CITY_PERSON_SIZE = 5000;//size of people in this city
public static float FATALITY_RATE = 0.01f;//fatality rate
public static int DIE_TIME = 100;//from diagnosis to death
public static double DIE_VARIANCE = 1;//variance of death time
/**
 * range of city
 */
public static final int CITY_WIDTH = 700;
public static final int CITY_HEIGHT = 800;

public static final float MASK = 0.2f;//have mask
public static final float MASK_RATE = 0.5f;//rate of people have mask
```

BROAD\_RATE is the probability that a normal person who distance with infected Person is closer than safe distance would get infected without any protection.

SHADOW\_TIME=140 means COVID-19 incubation period,in this period infected person may appear normal.

HOSPITAL\_RECEIVE\_TIME is the necessary time for hospital tracking confirmed patients and assigning bed for them.

BED\_COUNT is the number of bed in hospital.Usually,It would equal to CITY\_PERSON\_SIZE/1000\*4,because there are 4 beds for every thousand people in hospital.

Quarantine\_BED\_COUNT is the number of bed in quarantine area.If it equal to 0, means there is no quarantine area.

Quarantine\_WAIT\_TIME is the time for people in quarantine must wait.

R and K are decided by the type of virus, according to the information in internet,The R factors is 3 and K factors is 0.1 for COVID-19.  $R = \text{BROAD\_RATE}/\text{CURE\_RATE}$ ;K means the probability of a infected person become super-spreaders who can spread virus easier.

CURE\_RATE is the probability that a infected person recovered in a unit time, it decided by R and BROAD\_RATE,because We can approximately say that  $R = \text{BROAD\_RATE}/\text{CURE\_RATE}$ .

RE\_INFECTED RATE is 0.2,because only 20 percent of those who recover become re-infected with COVID-19, thus,in the project, the real BROAD\_RATE for recover person is equal to  $\text{BROAD\_RATE} * \text{RE\_INFECTED\_RATE}$ .

BROAD\_RATE\_SUPER is the probability that a normal person who distance with super-spreaders is closer than safe distance would get infected without any protection.Because super-spreaders can cause 80% of all infection,besides, the number of super-spreaders divide by all patients is K.

$$((1-K) * \text{BROAD\_RATE}) / (K * \text{BROAD\_RATE\_SUPER}) = 20/80$$

$$\text{BROAD\_RATE\_SUPER} = 4 * (1-K) * \text{BROAD\_RATE} / K;$$

HARD\_TIME=140;It is because many People will react strongly when they infected,after this hard time they can feel better and so that person can get chance to recover.

FATALITY\_RATE=0.01;According to the information from WHO,the fatality rate of COVID-19 is 1%.

MASK = 0.2f;It is said that this mask can reduce BROAD\_RATE to 20%.

MASK\_RATE = 0.5f;It is said that 50% ( $\text{MASK\_RATE} * 100\%$ )of person are willing to wear mask.

```
public static int CITY_NUMBER= 1; //If CITY_NUMBER=1,all person would set around one center;else, there are two centers  
public static int INITINFECTED_MODEL= 2; //if INITINFECTED_MODEL=1 choose ORIGINAL_COUNT people as origin infected patie
```

In Factors class, we can change CITY\_NUMBER;If CITY\_NUMBER=1, all person would set around one center(one city);If CITY\_NUMBER=others, there are two centers(two city).

If we change INITINFECTED\_MODEL=1,Project would randomly choose ORIGINAL\_COUNT number of people as origin infected patients;If INITINFECTED\_MODEL=2, 60 infection sources are setting at left, center and right on average.if INITINFECTED\_MODEL=3,at the beginning ,only south part of population would appear 20 patients.

#### 4. Implementation :

## 4.1 The k and R factors of the disease

Factors.CURE\_RATE and Factors.BROAD\_RATE\_SUPER are decided by K and R.

```
public void beInfected() {
    float fate = new Random().nextFloat();
    if (fate < Factors.K ){
        Super=true;
    }
    state = State.SHADOW;
    infectedTime = Graph.worldTime;//time start from becoming shadow patient
}
```

```

//cure chance for confirmed after hard time
if(Graph.worldTime-confirmedTime>=Factors.HARD_TIME){
    if (state == State.CONFIRMED&& dieMoment == 0 ) {
        float destiny=new Random().nextFloat();
        if(destiny<=Factors.CURE_RATE){
            state = State.NORMAL;
            dieMoment = 0;
            Super=false;
            Cure=true;
        }
    }
}

//cure chance for freeze after hard time
if(Graph.worldTime-confirmedTime>=(Factors.HARD_TIME)){
    if (state == State.FREEZE ) {
        float destiny=new Random().nextFloat();
        if(destiny<=Factors.CURE_RATE){
            state = State.NORMAL;
            dieMoment = 0;
            Super=false;
            Cure=true;
            Hospital.getInstance().returnBed(useBed);
            Random random=new Random();
            if(Graph.worldTime%2==0){ //leave hospital to random city
                int x=(int) (100 * random.nextGaussian() + city1.getCenterX());
                int y=(int) (100 * random.nextGaussian() + city1.getCenterY());
                if (x > 700) x = 700;
                setX(x);
                setY(y);
            }else{
                int x=(int) (100 * random.nextGaussian() + city2.getCenterX());
                int y=(int) (100 * random.nextGaussian() + city2.getCenterY());
                if (x > 700) x = 700;
                setX(x);
                setY(y);
            }
        }
    }
}

//update infection
List<Person> people = Population.getInstance().personList;
if (state >= State.SHADOW) {
    return;
}

//people below safe distance with each other can be infected randomly
for (Person person : people) {
    //Normal,hospital,Isolating and death people never infect others
    if (person.getState() == State.NORMAL||person.getState() == State.DEATH||person.getIsolating()||person.getState() == State.FREEZE) {
        continue;
    }
}

```

```

        float fate = new Random().nextFloat();
        float risk= Factors.BROAD_RATE;
        if(person.getSuper()){//whether super Infector
            risk=Factors.BROAD_RATE_SUPER;
        }

        if(this.Cure){//Only 20 percent of those who recover would infected again
            risk=risk*Factors.RE_INFECTED_RATE;
        }
        if (this.mask()){
            risk=risk*Factors.MASK;
        }
        if(person.mask()){
            risk=risk*Factors.MASK;
        }

        if (fate < risk && distance(person) < SAFE_DIST) {
            this.beInfected();
            break;
        }
    }
}

```

## 4.2 The population density

```

//different population density distribution
City city1 = new City( centerX: 200, centerY: 200);
City city2 = new City( centerX: 500, centerY: 500);
for (int i = 0; i < 2000; i++) {
    Random random = new Random();
    int x = (int) (100 * random.nextGaussian() + city1.getCenterX());
    int y = (int) (100 * random.nextGaussian() + city1.getCenterY());
    if (x > 700) x = 700;
    personList.add(new Person(city1, x, y));
}

for (int i = 0; i < 3000; i++) {
    Random random = new Random();
    int x = (int) (100 * random.nextGaussian() + city2.getCenterX());
    int y = (int) (100 * random.nextGaussian() + city2.getCenterY());
    if (x > 700) x = 700;
    personList.add(new Person(city2, x, y));
}

//average infection in the whole map
List<Person> people = Population.getInstance().getPersonList();
//left section
for (int i = 0; i < 20; i++) {
    Person person;
    do {
        person = people.get(new Random().nextInt( bound: people.size() - 1));
    } while (person.isInfected() || person.getX()>230);
    person.beInfected();
}

//central section
for (int i = 0; i < 20; i++) {
    Person person;
    do {
        person = people.get(new Random().nextInt( bound: people.size() - 1));
    } while (person.isInfected() || (person.getX()<230 || person.getX()>460));
    person.beInfected();
}

//right section
for (int i = 0; i < 20; i++) {
    Person person;
    do {
        person = people.get(new Random().nextInt( bound: people.size() - 1));
    } while (person.isInfected() || person.getX()<460);
    person.beInfected();
}
}

```

## 4.3 The usage and effectiveness of masks

```

public boolean mask(){
    float possibility = new Random().nextFloat();
    if(possibility <= Factors.MASK_RATE)//different type of masks have distinct rate of blocking virus
        return true;
    else return false;
}

```

```

float fate = new Random().nextFloat();
if(this.mask()){
    if(person.mask()){//both with mask
        if (fate < Factors.MASK * Factors.MASK && distance(person) < SAFE_DIST) {
            this.beInfected();
            break;
        }
    }
    else {//one with mask
        if (fate < Factors.MASK * Factors.BROAD_RATE && distance(person) < SAFE_DIST) {
            this.beInfected();
            break;
        }
    }
}
else {
    if (fate < Factors.BROAD_RATE && distance(person) < SAFE_DIST) {
        this.beInfected();
        break;
    }
}
}

```

#### 4.4 The prevalence of testing and contact tracing

```

public static double stdGaussian(double sigma, double u) {
    double X = randomGen.nextGaussian();
    return sigma * X + u;
}

public boolean wantMove() {
    return MathUtil.stdGaussian(sigma, Factors.Contact_Intention) > 0;
}

```

#### 4.5 Any barriers to entry (including quarantining) into the subject area

```

//if across the boundary of city,people need Isolation
if((getY()-400)*(move.getY()-400)<0){
    needIsolation=true;
    if(move.getY()<400){
        city=new City( centerX: 200, centerY: 200);
    }else{
        city=new City( centerX: 500, centerY: 500);
    }
}

```

```

//update state of people
public void update() {
    //if (state == State.FREEZE || state == State.DEATH) {
    if (state == State.DEATH) {

        return;//don't need to update
    }
    //update people for Quarantine
    if(needIsolation){
        Bed bed = Quarantine.getInstance().pickBed();//find empty beds
        if (bed == null) {
            //System.out.println("No beds!");
        } else {
            useBed = bed;
            needIsolation=false;
            Isolating=true;
            isolationMoment=Graph.worldTime;
            setX(bed.getX());
            setY(bed.getY());
            bed.setEmpty(false);
        }
    }
    //leave Quarantine,only the person who appear normal and wait enough time can leave

    if(Isolating){
        if(Graph.worldTime-isolationMoment>=Factors.Quarantine_WAIT_TIME &&state!=State.CONFIRMED){
            Isolating=false;
            Quarantine.getInstance().returnBed(useBed);
            Random random=new Random();
            //leave area to city
            int x=(int) (100 * random.nextGaussian() + city.getCenterX());
            int y=(int) (100 * random.nextGaussian() + city.getCenterX());
            if (x > 700) x = 700;
            setX(x);
            setY(y);

        }
    }
}

```

## 4.6 Other factors--bed (hospital) count

```

private Hospital() {
    super(HOSPITAL_X, y:HOSPITAL_Y + 10);//position of hospital
    //adjust the range of hospital according to beds
    if (Factors.BED_COUNT == 0) {
        width = 0;
        height = 0;
    }
    int column = Factors.BED_COUNT / 100;
    width = column * 6;
    for (int i = 0; i < column; i++) {
        for (int j = 10; j <= 60; j += 6) {
            Bed bed = new Bed( x: point.getX() + i * 6, y: point.getY() + j);
            beds.add(bed);
            if (beds.size() >= Factors.BED_COUNT) break;
        }
    }
}

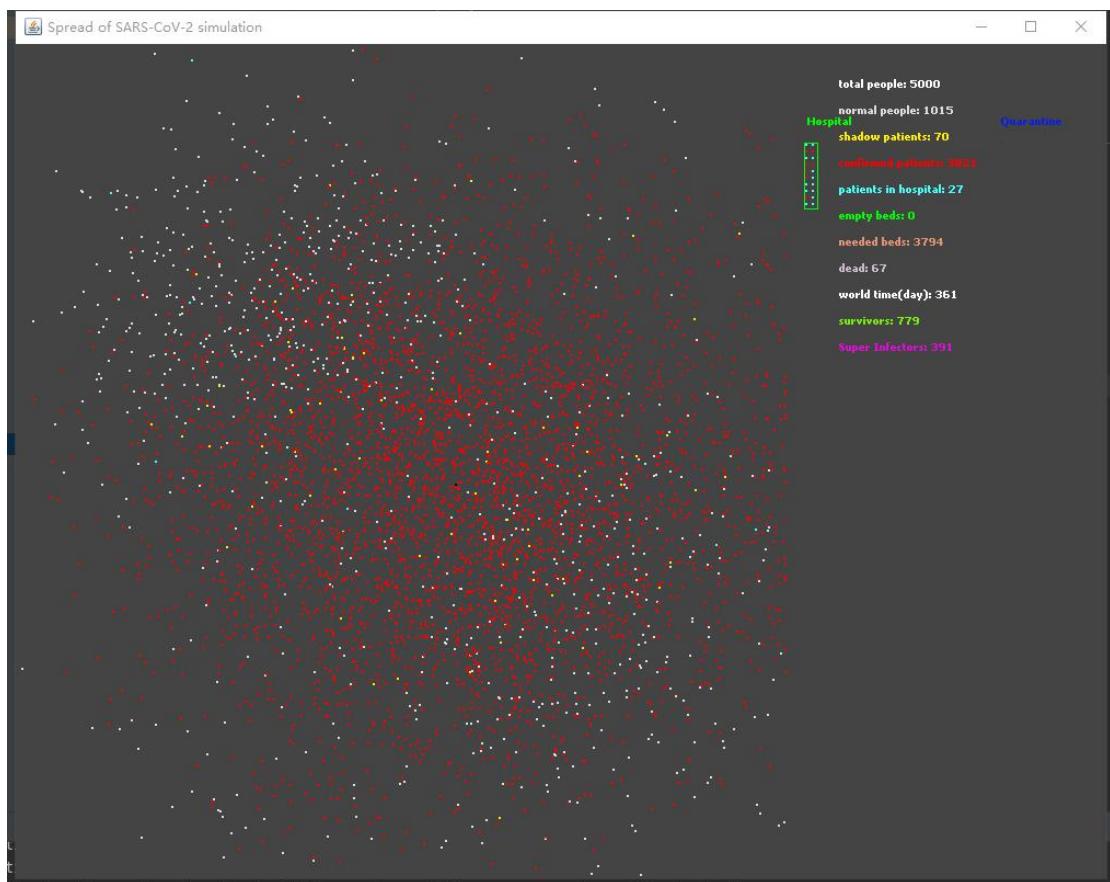
```

```
//update dead
if ((state == State.CONFIRMED || state == State.FREEZE) && Graph.worldTime >= dieMoment && dieMoment > 0) {
    state = State.DEATH;
    Hospital.getInstance().returnBed(useBed);
    setX(400);
    setY(400);
}
```

## 5. Output

### 5.1 The k and R factors of the disease

#### 5.1.1 The k and R factors of covid-19(k=0.1,R=3)



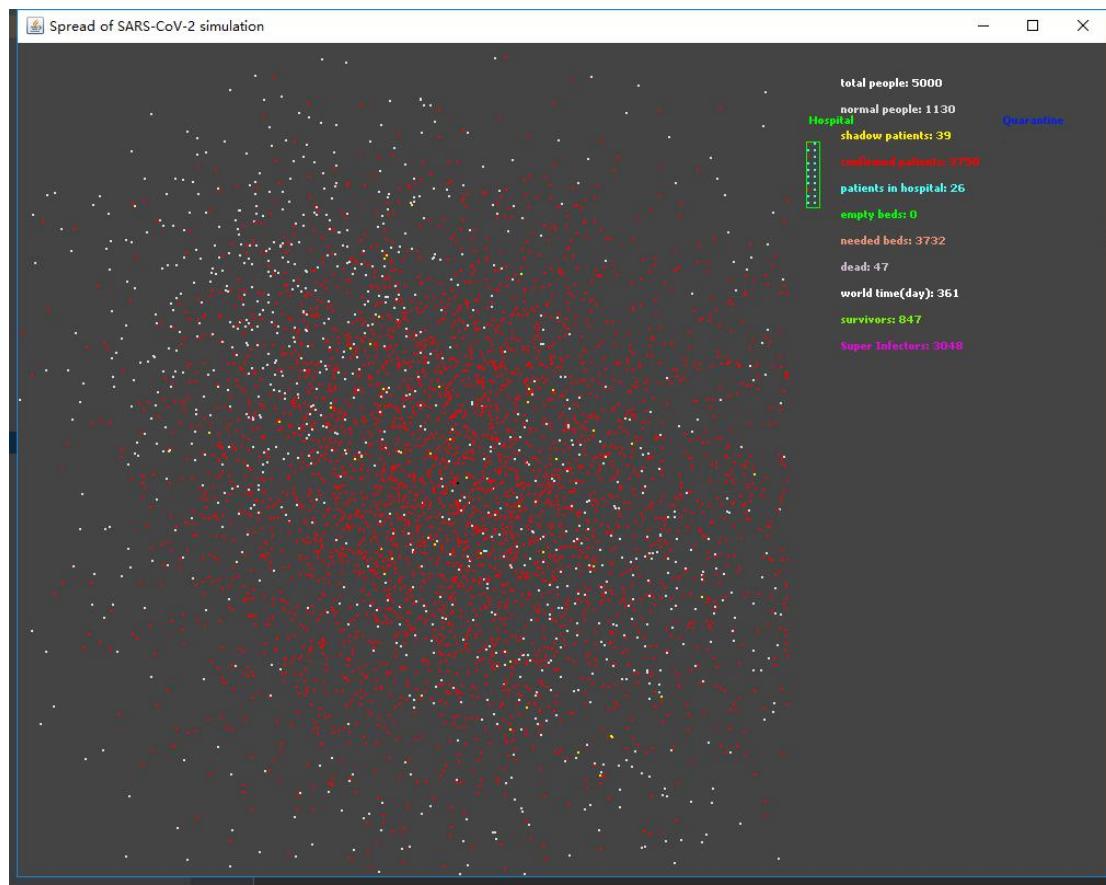
```
 Main x
"C:\Program Files\Java\jdk1.8.0_111\bin\java.exe" ...
Time: 10 days;normal people: 4137 ;shadow patients: 458 ;confirmed patients: 405 ;survivors: 0 ;super-spreaders: 78 ;dead: 0
Time: 20 days;normal people: 3503 ;shadow patients: 351 ;confirmed patients: 1144 ;survivors: 17 ;super-spreaders: 136 ;dead: 2
Time: 30 days;normal people: 3051 ;shadow patients: 262 ;confirmed patients: 1676 ;survivors: 41 ;super-spreaders: 177 ;dead: 11
Time: 40 days;normal people: 2709 ;shadow patients: 217 ;confirmed patients: 2059 ;survivors: 72 ;super-spreaders: 207 ;dead: 15
Time: 50 days;normal people: 2465 ;shadow patients: 165 ;confirmed patients: 2350 ;survivors: 113 ;super-spreaders: 236 ;dead: 20
Time: 60 days;normal people: 2280 ;shadow patients: 126 ;confirmed patients: 2572 ;survivors: 159 ;super-spreaders: 256 ;dead: 22
Time: 70 days;normal people: 2113 ;shadow patients: 124 ;confirmed patients: 2735 ;survivors: 186 ;super-spreaders: 270 ;dead: 28
Time: 80 days;normal people: 1999 ;shadow patients: 87 ;confirmed patients: 2883 ;survivors: 233 ;super-spreaders: 280 ;dead: 31
Time: 90 days;normal people: 1911 ;shadow patients: 82 ;confirmed patients: 2974 ;survivors: 278 ;super-spreaders: 283 ;dead: 33
Time: 100 days;normal people: 1824 ;shadow patients: 82 ;confirmed patients: 3061 ;survivors: 306 ;super-spreaders: 285 ;dead: 33
Time: 110 days;normal people: 1748 ;shadow patients: 66 ;confirmed patients: 3151 ;survivors: 341 ;super-spreaders: 294 ;dead: 35
Time: 120 days;normal people: 1659 ;shadow patients: 87 ;confirmed patients: 3218 ;survivors: 355 ;super-spreaders: 307 ;dead: 36
Time: 130 days;normal people: 1599 ;shadow patients: 67 ;confirmed patients: 3297 ;survivors: 396 ;super-spreaders: 309 ;dead: 37
Time: 140 days;normal people: 1539 ;shadow patients: 64 ;confirmed patients: 3358 ;survivors: 422 ;super-spreaders: 326 ;dead: 39
Time: 150 days;normal people: 1492 ;shadow patients: 73 ;confirmed patients: 3394 ;survivors: 440 ;super-spreaders: 328 ;dead: 41
Time: 160 days;normal people: 1442 ;shadow patients: 67 ;confirmed patients: 3446 ;survivors: 461 ;super-spreaders: 338 ;dead: 43
Time: 170 days;normal people: 1381 ;shadow patients: 76 ;confirmed patients: 3500 ;survivors: 468 ;super-spreaders: 335 ;dead: 43
Time: 180 days;normal people: 1337 ;shadow patients: 61 ;confirmed patients: 3559 ;survivors: 490 ;super-spreaders: 348 ;dead: 43
Time: 190 days;normal people: 1316 ;shadow patients: 73 ;confirmed patients: 3563 ;survivors: 521 ;super-spreaders: 357 ;dead: 48
Time: 200 days;normal people: 1272 ;shadow patients: 81 ;confirmed patients: 3599 ;survivors: 525 ;super-spreaders: 360 ;dead: 48
Time: 210 days;normal people: 1224 ;shadow patients: 77 ;confirmed patients: 3648 ;survivors: 544 ;super-spreaders: 365 ;dead: 51
Time: 220 days;normal people: 1188 ;shadow patients: 63 ;confirmed patients: 3704 ;survivors: 543 ;super-spreaders: 370 ;dead: 53
Time: 230 days;normal people: 1141 ;shadow patients: 71 ;confirmed patients: 3734 ;survivors: 551 ;super-spreaders: 374 ;dead: 54
Time: 240 days;normal people: 1122 ;shadow patients: 79 ;confirmed patients: 3745 ;survivors: 588 ;super-spreaders: 378 ;dead: 54
Time: 250 days;normal people: 1091 ;shadow patients: 74 ;confirmed patients: 3779 ;survivors: 590 ;super-spreaders: 381 ;dead: 56
Time: 260 days;normal people: 1063 ;shadow patients: 63 ;confirmed patients: 3814 ;survivors: 613 ;super-spreaders: 378 ;dead: 60
Time: 270 days;normal people: 1042 ;shadow patients: 60 ;confirmed patients: 3838 ;survivors: 630 ;super-spreaders: 383 ;dead: 60
Time: 280 days;normal people: 1025 ;shadow patients: 56 ;confirmed patients: 3858 ;survivors: 639 ;super-spreaders: 390 ;dead: 61
Time: 290 days;normal people: 1033 ;shadow patients: 52 ;confirmed patients: 3852 ;survivors: 678 ;super-spreaders: 389 ;dead: 63
Time: 300 days;normal people: 1030 ;shadow patients: 63 ;confirmed patients: 3843 ;survivors: 699 ;super-spreaders: 394 ;dead: 64
Time: 310 days;normal people: 1029 ;shadow patients: 60 ;confirmed patients: 3847 ;survivors: 716 ;super-spreaders: 396 ;dead: 64
Time: 320 days;normal people: 1038 ;shadow patients: 54 ;confirmed patients: 3843 ;survivors: 742 ;super-spreaders: 403 ;dead: 65
Time: 330 days;normal people: 1039 ;shadow patients: 73 ;confirmed patients: 3822 ;survivors: 756 ;super-spreaders: 406 ;dead: 66
Time: 340 days;normal people: 1029 ;shadow patients: 65 ;confirmed patients: 3840 ;survivors: 760 ;super-spreaders: 400 ;dead: 66
Time: 350 days;normal people: 1037 ;shadow patients: 65 ;confirmed patients: 3832 ;survivors: 789 ;super-spreaders: 394 ;dead: 66
Time: 360 days;normal people: 1019 ;shadow patients: 63 ;confirmed patients: 3851 ;survivors: 779 ;super-spreaders: 392 ;dead: 67

Process finished with exit code 0
```

### 5.1.2 K=0.1;R=0.5;



### 5.1.3 k=0.8;R=3

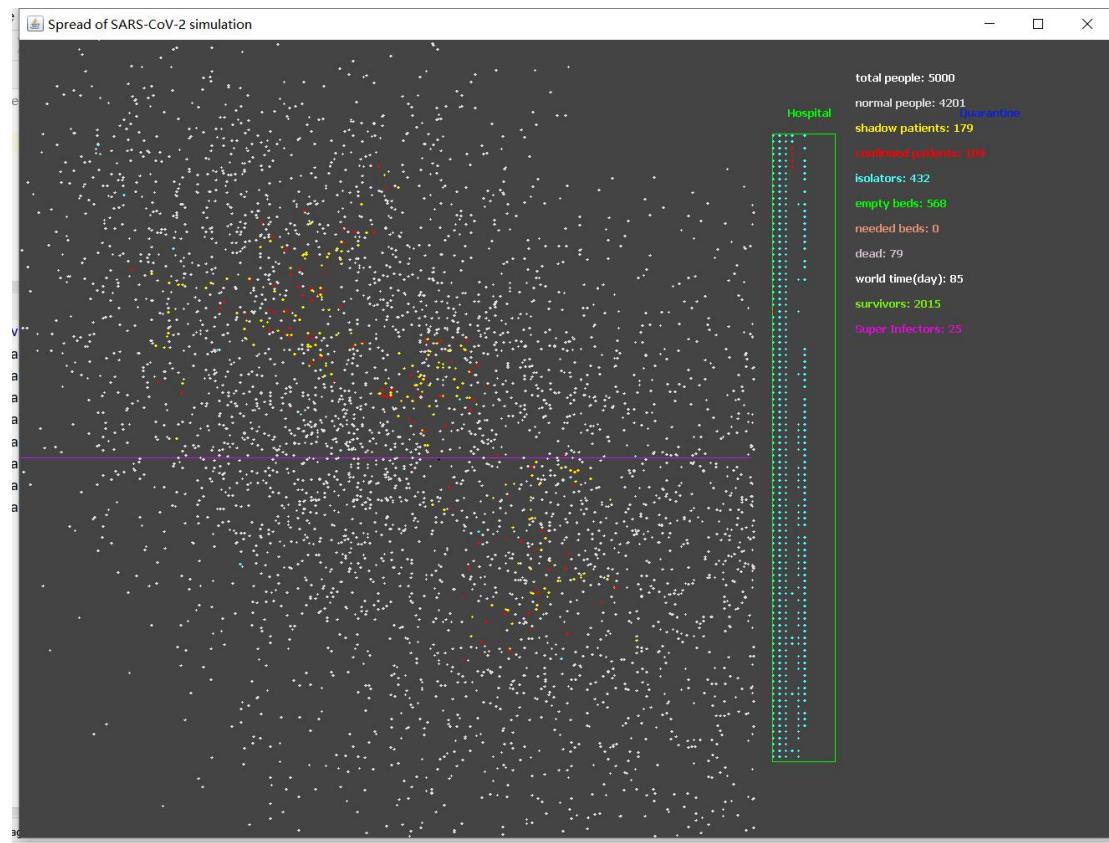


```

Run: Main
  "C:\Program Files\Java\jdk1.8.0_111\bin\java.exe" ...
  Time: 10 days;normal people: 4286 ;shadow patients: 391 ;confirmed patients: 323 ;survivors: 0 ;super-spreaders: 551 ;dead: 0
  Time: 20 days;normal people: 3675 ;shadow patients: 339 ;confirmed patients: 982 ;survivors: 14 ;super-spreaders: 1049 ;dead: 4
  Time: 30 days;normal people: 3154 ;shadow patients: 293 ;confirmed patients: 1542 ;survivors: 40 ;super-spreaders: 1467 ;dead: 11
  Time: 40 days;normal people: 2747 ;shadow patients: 235 ;confirmed patients: 2005 ;survivors: 68 ;super-spreaders: 1782 ;dead: 13
  Time: 50 days;normal people: 2456 ;shadow patients: 199 ;confirmed patients: 2330 ;survivors: 108 ;super-spreaders: 2028 ;dead: 15
  Time: 60 days;normal people: 2248 ;shadow patients: 143 ;confirmed patients: 2591 ;survivors: 148 ;super-spreaders: 2199 ;dead: 18
  Time: 70 days;normal people: 2078 ;shadow patients: 115 ;confirmed patients: 2787 ;survivors: 188 ;super-spreaders: 2318 ;dead: 20
  Time: 80 days;normal people: 1965 ;shadow patients: 101 ;confirmed patients: 2912 ;survivors: 244 ;super-spreaders: 2407 ;dead: 22
  Time: 90 days;normal people: 1867 ;shadow patients: 75 ;confirmed patients: 3032 ;survivors: 279 ;super-spreaders: 2482 ;dead: 26
  Time: 100 days;normal people: 1804 ;shadow patients: 72 ;confirmed patients: 3096 ;survivors: 322 ;super-spreaders: 2528 ;dead: 28
  Time: 110 days;normal people: 1765 ;shadow patients: 58 ;confirmed patients: 3148 ;survivors: 373 ;super-spreaders: 2560 ;dead: 29
  Time: 120 days;normal people: 1717 ;shadow patients: 63 ;confirmed patients: 3191 ;survivors: 415 ;super-spreaders: 2597 ;dead: 29
  Time: 130 days;normal people: 1671 ;shadow patients: 64 ;confirmed patients: 3235 ;survivors: 450 ;super-spreaders: 2630 ;dead: 30
  Time: 140 days;normal people: 1606 ;shadow patients: 66 ;confirmed patients: 3298 ;survivors: 481 ;super-spreaders: 2672 ;dead: 30
  Time: 150 days;normal people: 1562 ;shadow patients: 68 ;confirmed patients: 3339 ;survivors: 519 ;super-spreaders: 2705 ;dead: 31
  Time: 160 days;normal people: 1521 ;shadow patients: 60 ;confirmed patients: 3387 ;survivors: 541 ;super-spreaders: 2740 ;dead: 32
  Time: 170 days;normal people: 1460 ;shadow patients: 66 ;confirmed patients: 3442 ;survivors: 562 ;super-spreaders: 2799 ;dead: 32
  Time: 180 days;normal people: 1431 ;shadow patients: 54 ;confirmed patients: 3482 ;survivors: 597 ;super-spreaders: 2827 ;dead: 33
  Time: 190 days;normal people: 1386 ;shadow patients: 70 ;confirmed patients: 3509 ;survivors: 627 ;super-spreaders: 2856 ;dead: 35
  Time: 200 days;normal people: 1362 ;shadow patients: 45 ;confirmed patients: 3557 ;survivors: 660 ;super-spreaders: 2878 ;dead: 36
  Time: 210 days;normal people: 1337 ;shadow patients: 63 ;confirmed patients: 3562 ;survivors: 687 ;super-spreaders: 2896 ;dead: 38
  Time: 220 days;normal people: 1326 ;shadow patients: 48 ;confirmed patients: 3588 ;survivors: 717 ;super-spreaders: 2900 ;dead: 38
  Time: 230 days;normal people: 1296 ;shadow patients: 61 ;confirmed patients: 3604 ;survivors: 725 ;super-spreaders: 2917 ;dead: 39
  Time: 240 days;normal people: 1280 ;shadow patients: 52 ;confirmed patients: 3628 ;survivors: 746 ;super-spreaders: 2931 ;dead: 40
  Time: 250 days;normal people: 1262 ;shadow patients: 54 ;confirmed patients: 3644 ;survivors: 759 ;super-spreaders: 2943 ;dead: 40
  Time: 260 days;normal people: 1256 ;shadow patients: 48 ;confirmed patients: 3655 ;survivors: 778 ;super-spreaders: 2949 ;dead: 41
  Time: 270 days;normal people: 1239 ;shadow patients: 49 ;confirmed patients: 3671 ;survivors: 793 ;super-spreaders: 2964 ;dead: 41
  Time: 280 days;normal people: 1214 ;shadow patients: 55 ;confirmed patients: 3689 ;survivors: 808 ;super-spreaders: 2978 ;dead: 42
  Time: 290 days;normal people: 1171 ;shadow patients: 56 ;confirmed patients: 3730 ;survivors: 794 ;super-spreaders: 3013 ;dead: 43
  Time: 300 days;normal people: 1140 ;shadow patients: 57 ;confirmed patients: 3768 ;survivors: 789 ;super-spreaders: 3041 ;dead: 43
  Time: 310 days;normal people: 1113 ;shadow patients: 58 ;confirmed patients: 3786 ;survivors: 774 ;super-spreaders: 3069 ;dead: 43
  Time: 320 days;normal people: 1088 ;shadow patients: 68 ;confirmed patients: 3807 ;survivors: 768 ;super-spreaders: 3088 ;dead: 45
  Time: 330 days;normal people: 1095 ;shadow patients: 52 ;confirmed patients: 3807 ;survivors: 783 ;super-spreaders: 3080 ;dead: 46
  Time: 340 days;normal people: 1109 ;shadow patients: 48 ;confirmed patients: 3797 ;survivors: 807 ;super-spreaders: 3072 ;dead: 46
  Time: 350 days;normal people: 1118 ;shadow patients: 55 ;confirmed patients: 3781 ;survivors: 825 ;super-spreaders: 3067 ;dead: 46
  Time: 360 days;normal people: 1127 ;shadow patients: 49 ;confirmed patients: 3777 ;survivors: 842 ;super-spreaders: 3051 ;dead: 47

```

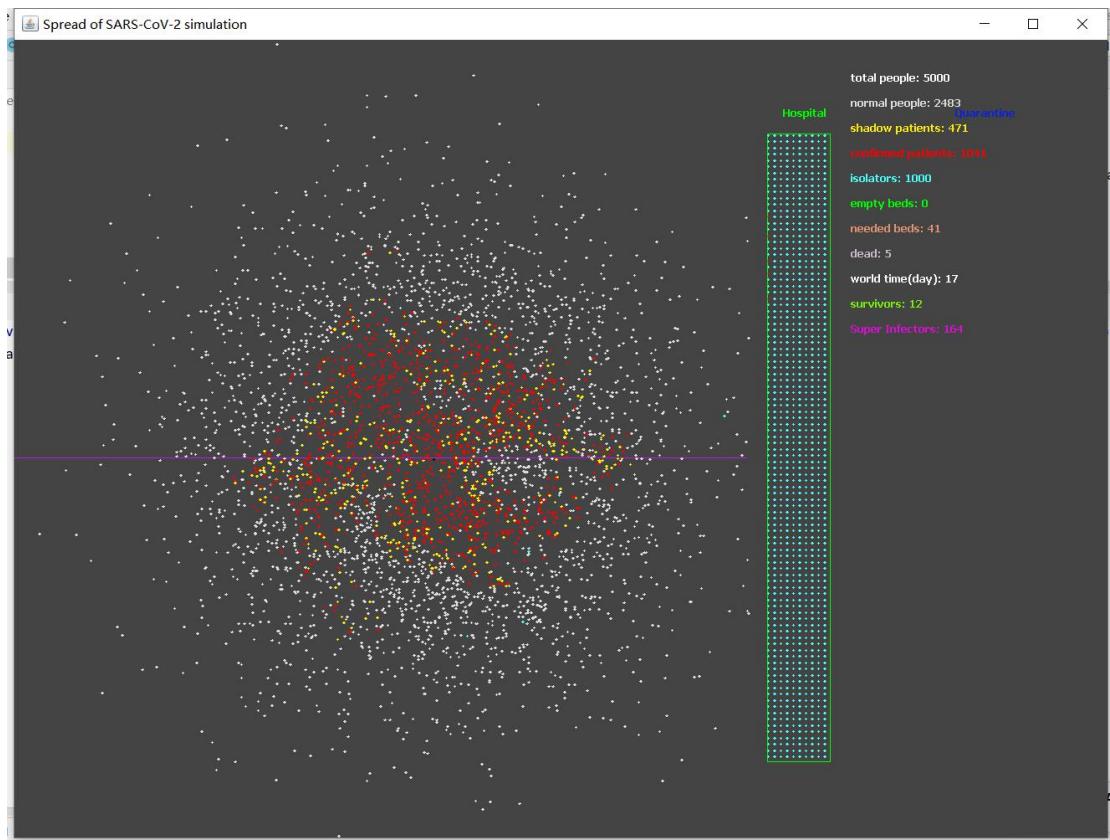
## 5.2 The population density



```
Time: 10 days;normal people: 3880 ;shadow patients: 506 ;confirmed patients: 614 ;left patients: 186 ;middel patients: 207 ;right patients: 482 ;dead: 0
Time: 20 days;normal people: 3299 ;shadow patients: 253 ;confirmed patients: 1439 ;left patients: 127 ;middel patients: 239 ;right patients: 324 ;dead: 9
Time: 30 days;normal people: 3726 ;shadow patients: 245 ;confirmed patients: 998 ;left patients: 78 ;middel patients: 147 ;right patients: 197 ;dead: 31
Time: 40 days;normal people: 3781 ;shadow patients: 266 ;confirmed patients: 914 ;left patients: 81 ;middel patients: 168 ;right patients: 191 ;dead: 39
Time: 50 days;normal people: 4442 ;shadow patients: 149 ;confirmed patients: 364 ;left patients: 85 ;middel patients: 172 ;right patients: 165 ;dead: 45
Time: 60 days;normal people: 4270 ;shadow patients: 121 ;confirmed patients: 555 ;left patients: 68 ;middel patients: 128 ;right patients: 110 ;dead: 54
Time: 70 days;normal people: 4125 ;shadow patients: 213 ;confirmed patients: 600 ;left patients: 89 ;middel patients: 197 ;right patients: 84 ;dead: 62
Time: 80 days;normal people: 4176 ;shadow patients: 127 ;confirmed patients: 622 ;left patients: 26 ;middel patients: 136 ;right patients: 41 ;dead: 75
Time: 90 days;normal people: 4133 ;shadow patients: 182 ;confirmed patients: 600 ;left patients: 43 ;middel patients: 188 ;right patients: 86 ;dead: 85
Time: 100 days;normal people: 4069 ;shadow patients: 171 ;confirmed patients: 665 ;left patients: 48 ;middel patients: 172 ;right patients: 96 ;dead: 95
```

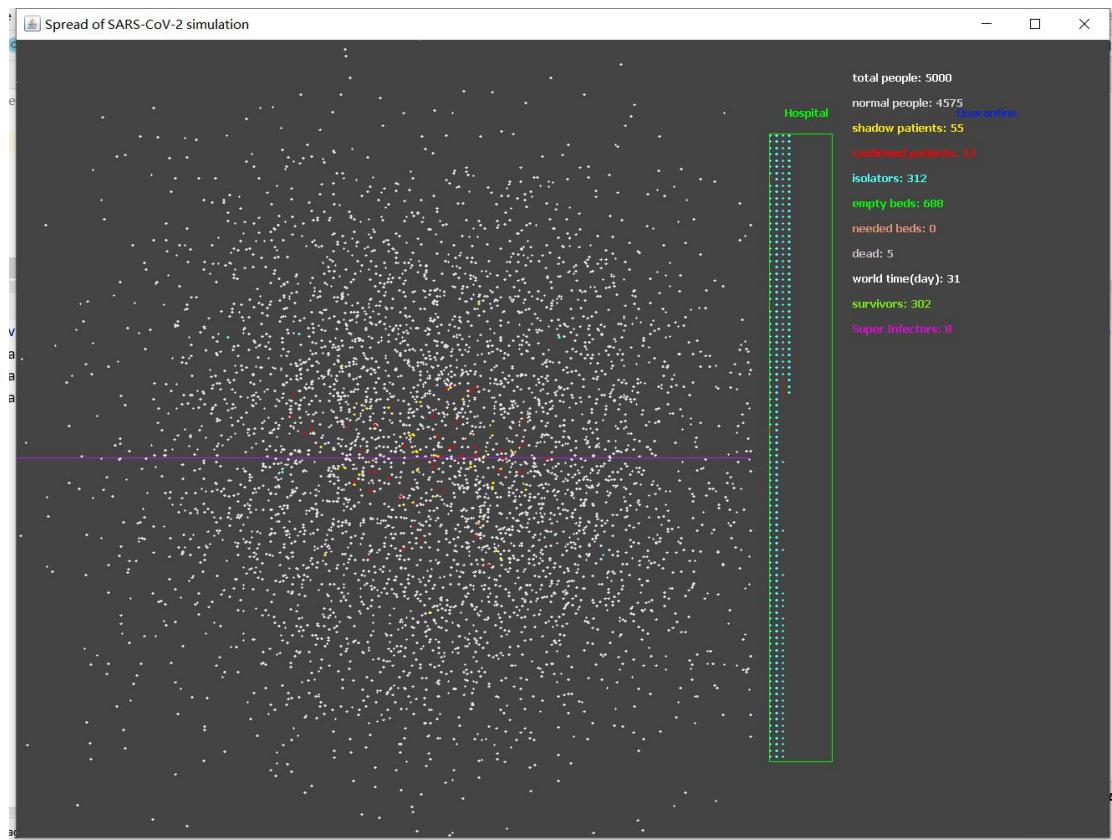
## 5.3 The usage and effectiveness of masks

### 5.3.1 people without mask:



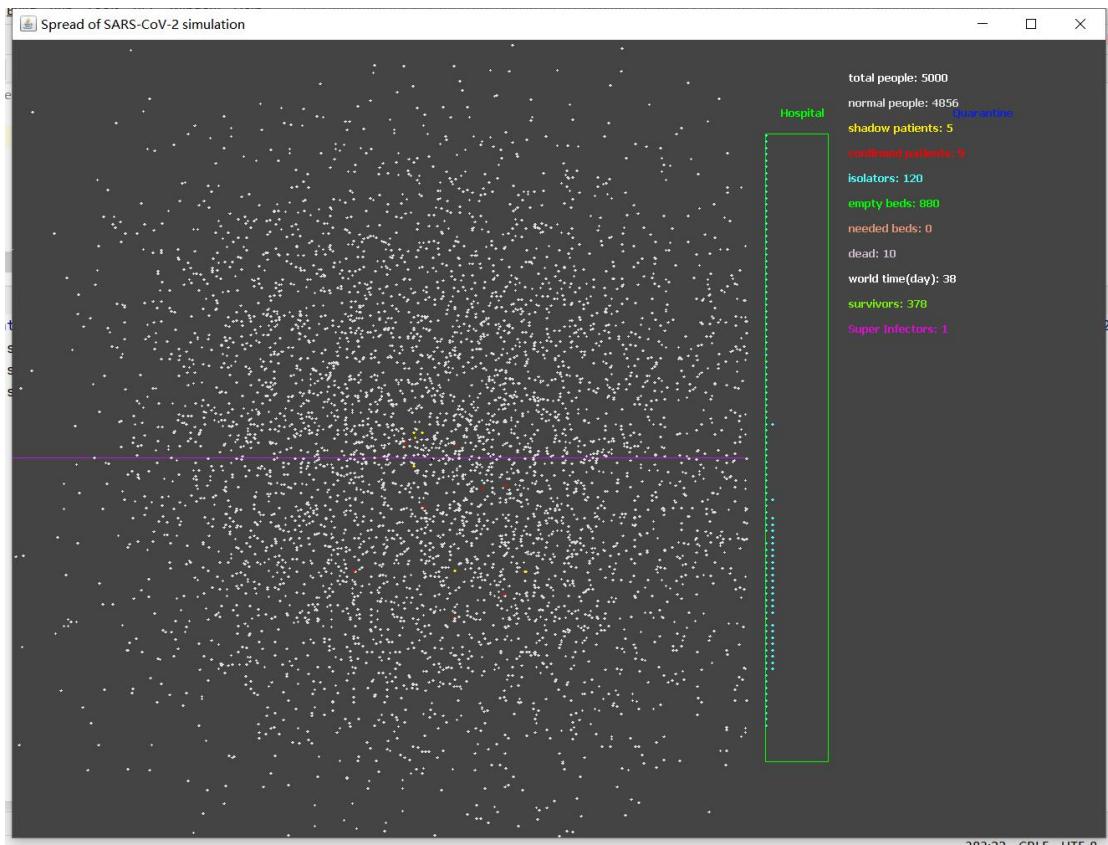
```
Time: 10 days;normal people: 3383 ;shadow patients: 832 ;confirmed patients: 785 ;north patients: 529 ;south patients: 815 ;dead: 0
Time: 20 days;normal people: 2444 ;shadow patients: 436 ;confirmed patients: 2104 ;north patients: 735 ;south patients: 806 ;dead: 15
Time: 30 days;normal people: 3197 ;shadow patients: 273 ;confirmed patients: 1479 ;north patients: 377 ;south patients: 375 ;dead: 51
Time: 40 days;normal people: 3712 ;shadow patients: 284 ;confirmed patients: 930 ;north patients: 239 ;south patients: 214 ;dead: 74
Time: 50 days;normal people: 3780 ;shadow patients: 233 ;confirmed patients: 907 ;north patients: 218 ;south patients: 197 ;dead: 80
Time: 60 days;normal people: 3836 ;shadow patients: 212 ;confirmed patients: 852 ;north patients: 199 ;south patients: 192 ;dead: 100
Time: 70 days;normal people: 3878 ;shadow patients: 239 ;confirmed patients: 775 ;north patients: 198 ;south patients: 192 ;dead: 108
Time: 80 days;normal people: 3794 ;shadow patients: 262 ;confirmed patients: 831 ;north patients: 232 ;south patients: 215 ;dead: 113
Time: 90 days;normal people: 3706 ;shadow patients: 249 ;confirmed patients: 921 ;north patients: 246 ;south patients: 198 ;dead: 124
Time: 100 days;normal people: 3715 ;shadow patients: 232 ;confirmed patients: 914 ;north patients: 207 ;south patients: 209 ;dead: 139
Time: 110 days;normal people: 3715 ;shadow patients: 232 ;confirmed patients: 914 ;north patients: 207 ;south patients: 209 ;dead: 139
Time: 120 days;normal people: 4452 ;shadow patients: 84 ;confirmed patients: 307 ;north patients: 160 ;south patients: 156 ;dead: 157
Time: 130 days;normal people: 4452 ;shadow patients: 84 ;confirmed patients: 307 ;north patients: 160 ;south patients: 156 ;dead: 157
```

### 5.3.2 people with KN90 mask:



```
Time: 10 days;normal people: 4729 ;shadow patients: 122 ;confirmed patients: 149 ;north patients: 116 ;south patients: 66 ;dead: 0
Time: 20 days;normal people: 4524 ;shadow patients: 93 ;confirmed patients: 379 ;north patients: 99 ;south patients: 69 ;dead: 4
Time: 30 days;normal people: 4602 ;shadow patients: 63 ;confirmed patients: 323 ;north patients: 39 ;south patients: 67 ;dead: 12
Time: 40 days;normal people: 4728 ;shadow patients: 39 ;confirmed patients: 214 ;north patients: 24 ;south patients: 42 ;dead: 19
Time: 50 days;normal people: 4821 ;shadow patients: 25 ;confirmed patients: 130 ;north patients: 17 ;south patients: 22 ;dead: 24
Time: 60 days;normal people: 4851 ;shadow patients: 26 ;confirmed patients: 94 ;north patients: 35 ;south patients: 12 ;dead: 29
Time: 70 days;normal people: 4822 ;shadow patients: 24 ;confirmed patients: 124 ;north patients: 27 ;south patients: 29 ;dead: 30
Time: 80 days;normal people: 4820 ;shadow patients: 32 ;confirmed patients: 117 ;north patients: 33 ;south patients: 19 ;dead: 31
Time: 90 days;normal people: 4830 ;shadow patients: 29 ;confirmed patients: 108 ;north patients: 25 ;south patients: 29 ;dead: 33
Time: 100 days;normal people: 4804 ;shadow patients: 32 ;confirmed patients: 129 ;north patients: 22 ;south patients: 36 ;dead: 35
Time: 110 days;normal people: 4810 ;shadow patients: 35 ;confirmed patients: 119 ;north patients: 21 ;south patients: 38 ;dead: 36
Time: 120 days;normal people: 4803 ;shadow patients: 33 ;confirmed patients: 126 ;north patients: 30 ;south patients: 30 ;dead: 38
Time: 130 days;normal people: 4791 ;shadow patients: 38 ;confirmed patients: 130 ;north patients: 24 ;south patients: 41 ;dead: 41
```

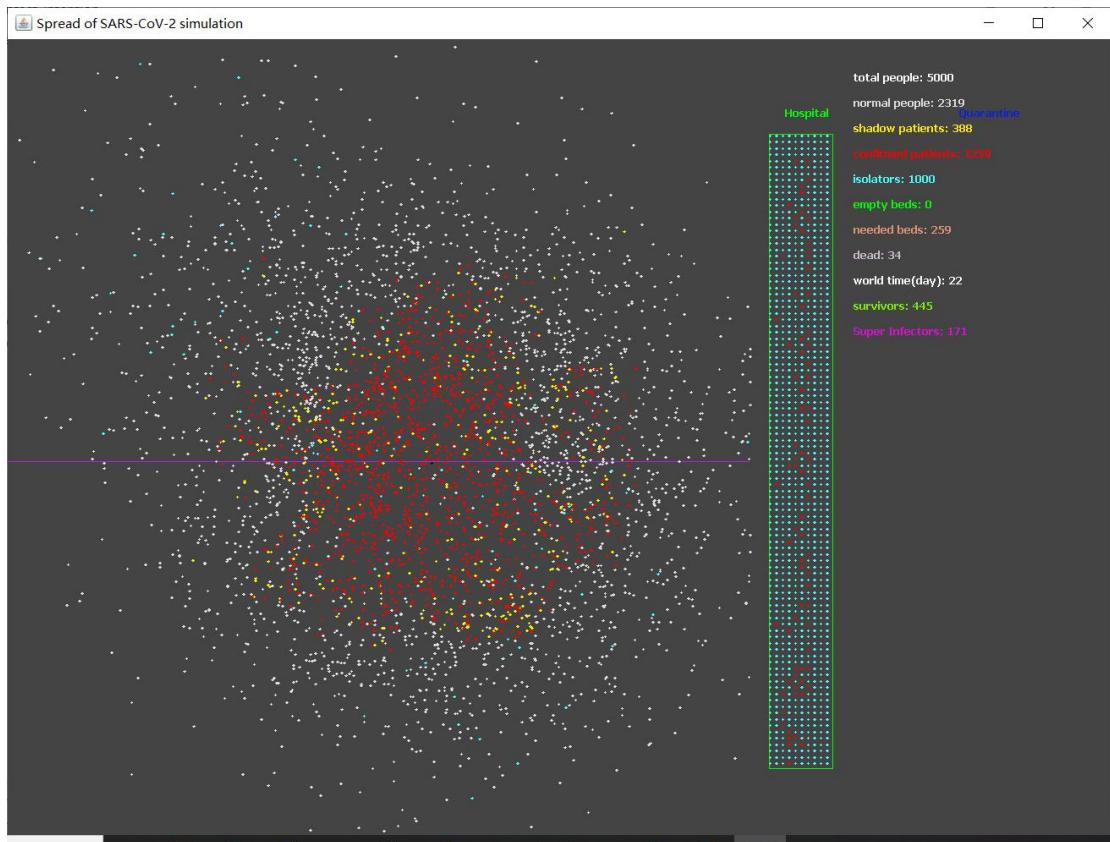
### 5.3.3 people with KN95 mask:



```
Time: 10 days;normal people: 4821 ;shadow patients: 64 ;confirmed patients: 115 ;north patients: 59 ;south patients: 52 ;dead: 0
Time: 20 days;normal people: 4732 ;shadow patients: 41 ;confirmed patients: 224 ;north patients: 41 ;south patients: 44 ;dead: 3
Time: 30 days;normal people: 4781 ;shadow patients: 35 ;confirmed patients: 175 ;north patients: 35 ;south patients: 26 ;dead: 9
Time: 40 days;normal people: 4859 ;shadow patients: 18 ;confirmed patients: 114 ;north patients: 18 ;south patients: 19 ;dead: 9
Time: 50 days;normal people: 4904 ;shadow patients: 15 ;confirmed patients: 72 ;north patients: 11 ;south patients: 12 ;dead: 9
Time: 60 days;normal people: 4909 ;shadow patients: 16 ;confirmed patients: 65 ;north patients: 13 ;south patients: 23 ;dead: 10
Time: 70 days;normal people: 4896 ;shadow patients: 15 ;confirmed patients: 79 ;north patients: 12 ;south patients: 23 ;dead: 10
Time: 80 days;normal people: 4899 ;shadow patients: 21 ;confirmed patients: 69 ;north patients: 9 ;south patients: 25 ;dead: 11
Time: 90 days;normal people: 4882 ;shadow patients: 27 ;confirmed patients: 79 ;north patients: 16 ;south patients: 35 ;dead: 12
Time: 100 days;normal people: 4874 ;shadow patients: 20 ;confirmed patients: 92 ;north patients: 18 ;south patients: 14 ;dead: 14
Time: 110 days;normal people: 4894 ;shadow patients: 17 ;confirmed patients: 74 ;north patients: 12 ;south patients: 21 ;dead: 15
Time: 120 days;normal people: 4920 ;shadow patients: 5 ;confirmed patients: 59 ;north patients: 10 ;south patients: 5 ;dead: 16
Time: 130 days;normal people: 4951 ;shadow patients: 4 ;confirmed patients: 29 ;north patients: 1 ;south patients: 6 ;dead: 16
```

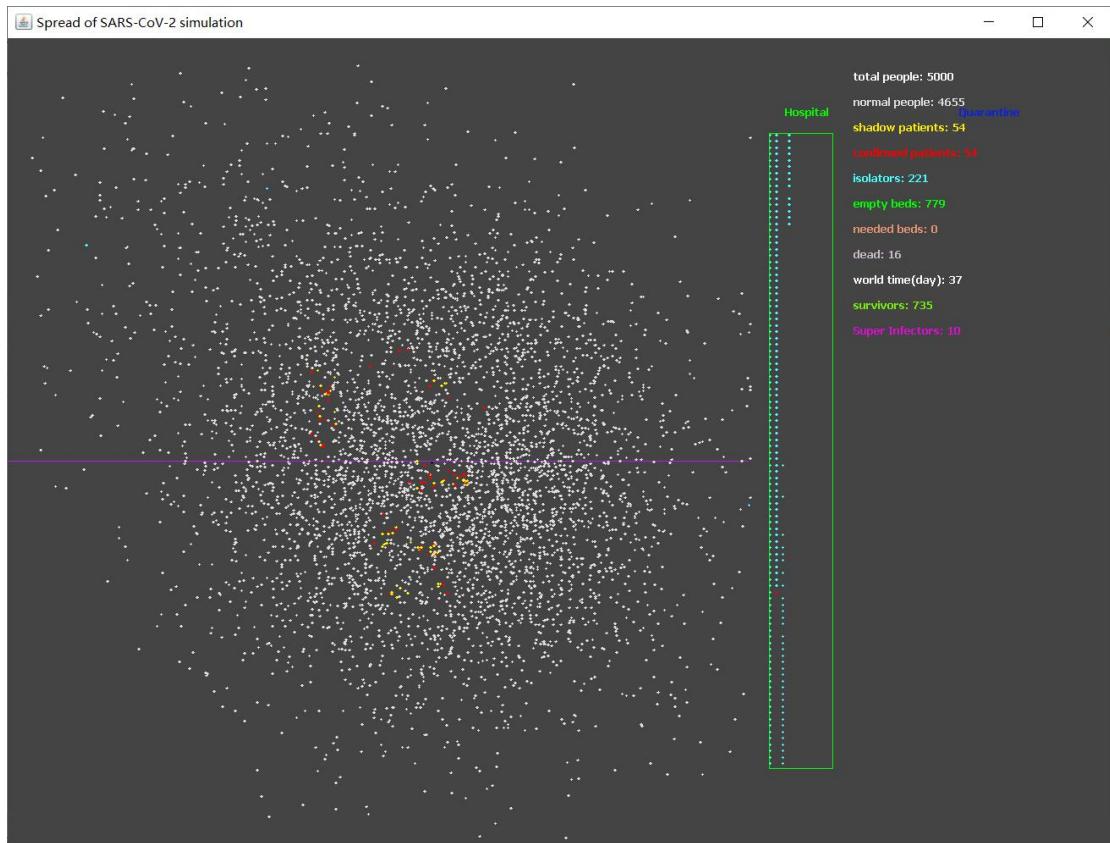
## 5.4 The prevalence of testing and contact tracing

### 5.4.1 people prefer to contact with each other



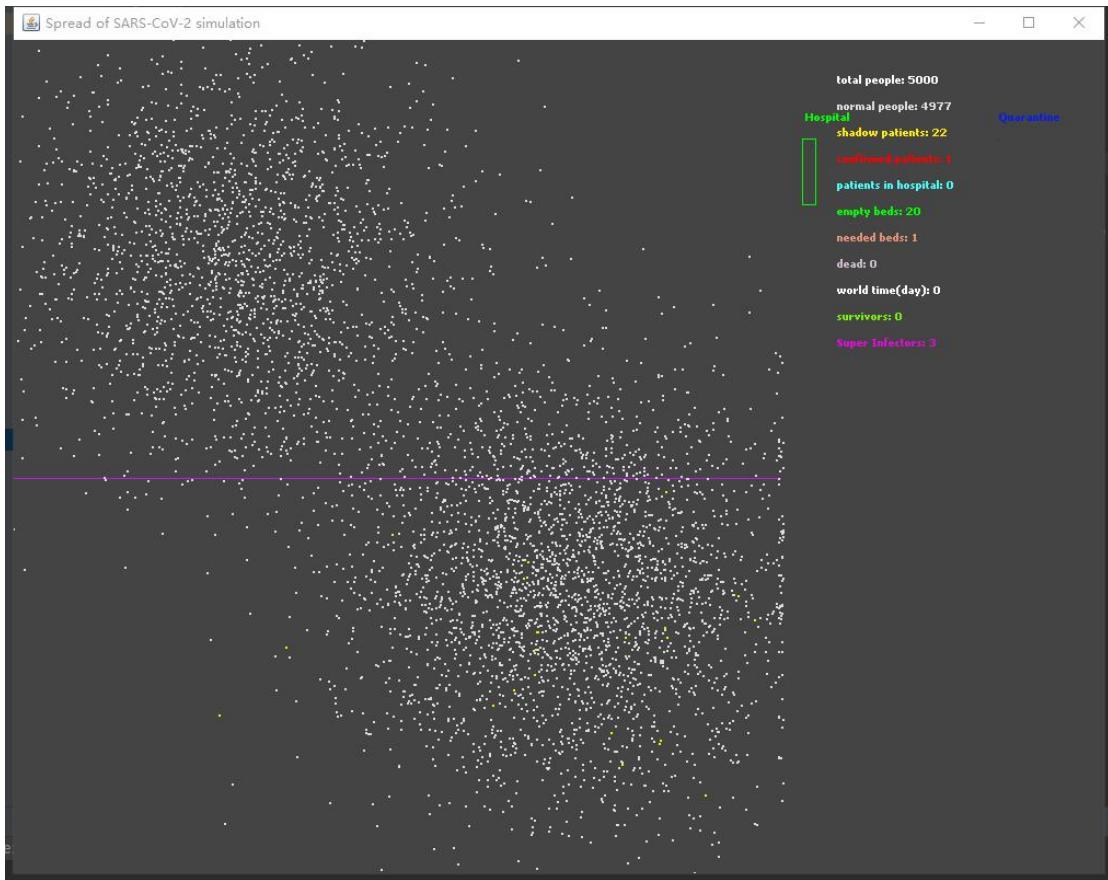
Time: 10 days; normal people: 3140 ; shadow patients: 876 ; confirmed patients: 984 ; dead: 0  
Time: 20 days; normal people: 2141 ; shadow patients: 446 ; confirmed patients: 2387 ; dead: 25  
Time: 30 days; normal people: 2919 ; shadow patients: 360 ; confirmed patients: 1660 ; dead: 61  
Time: 40 days; normal people: 3487 ; shadow patients: 265 ; confirmed patients: 1165 ; dead: 83  
Time: 50 days; normal people: 3655 ; shadow patients: 259 ; confirmed patients: 989 ; dead: 97  
Time: 60 days; normal people: 3798 ; shadow patients: 190 ; confirmed patients: 908 ; dead: 104  
Time: 70 days; normal people: 3839 ; shadow patients: 235 ; confirmed patients: 809 ; dead: 117  
Time: 80 days; normal people: 3762 ; shadow patients: 245 ; confirmed patients: 862 ; dead: 131  
Time: 90 days; normal people: 3771 ; shadow patients: 233 ; confirmed patients: 848 ; dead: 148  
Time: 100 days; normal people: 3683 ; shadow patients: 280 ; confirmed patients: 883 ; dead: 154

### 5.4.2 people prefer to stay at home

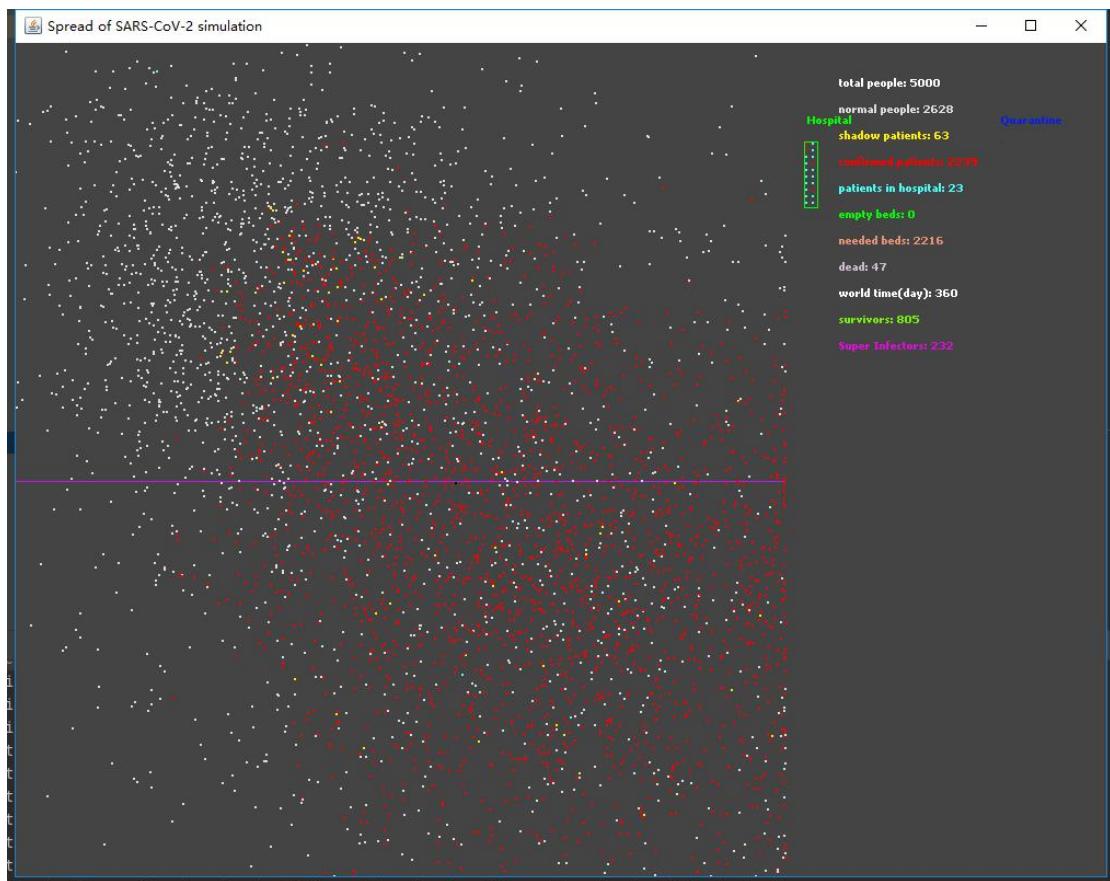


Time: 10 days;normal people: 4527 ;shadow patients: 196 ;confirmed patients: 277 ;dead: 0  
Time: 20 days;normal people: 4312 ;shadow patients: 95 ;confirmed patients: 590 ;dead: 3  
Time: 30 days;normal people: 4547 ;shadow patients: 61 ;confirmed patients: 378 ;dead: 14  
Time: 40 days;normal people: 4685 ;shadow patients: 49 ;confirmed patients: 250 ;dead: 16  
Time: 50 days;normal people: 4764 ;shadow patients: 31 ;confirmed patients: 185 ;dead: 20  
Time: 60 days;normal people: 4805 ;shadow patients: 30 ;confirmed patients: 143 ;dead: 22  
Time: 70 days;normal people: 4831 ;shadow patients: 24 ;confirmed patients: 120 ;dead: 25  
Time: 80 days;normal people: 4864 ;shadow patients: 13 ;confirmed patients: 98 ;dead: 25  
Time: 90 days;normal people: 4912 ;shadow patients: 6 ;confirmed patients: 56 ;dead: 26  
Time: 100 days;normal people: 4925 ;shadow patients: 11 ;confirmed patients: 36 ;dead: 28

## 5.5 Any barriers to entry (including quarantining) into the subject area



### 5.5.1 When no quarantine :



```
Time: 30 days;normal people: 4080 ;shadow patients: 107 ;confirmed patients: 804 ;north patients: 101 ;south patients: 799 ;dead: 9
Time: 60 days;normal people: 3934 ;shadow patients: 73 ;confirmed patients: 978 ;north patients: 175 ;south patients: 856 ;dead: 15
Time: 90 days;normal people: 3787 ;shadow patients: 66 ;confirmed patients: 1123 ;north patients: 228 ;south patients: 940 ;dead: 24
Time: 120 days;normal people: 3623 ;shadow patients: 71 ;confirmed patients: 1279 ;north patients: 304 ;south patients: 1026 ;dead: 31
Time: 150 days;normal people: 3497 ;shadow patients: 25 ;confirmed patients: 1447 ;north patients: 363 ;south patients: 1088 ;dead: 31
Time: 180 days;normal people: 3353 ;shadow patients: 72 ;confirmed patients: 1539 ;north patients: 437 ;south patients: 1153 ;dead: 36
Time: 210 days;normal people: 3271 ;shadow patients: 62 ;confirmed patients: 1630 ;north patients: 489 ;south patients: 1182 ;dead: 37
Time: 240 days;normal people: 3271 ;shadow patients: 62 ;confirmed patients: 1630 ;north patients: 489 ;south patients: 1182 ;dead: 37
Time: 270 days;normal people: 3147 ;shadow patients: 71 ;confirmed patients: 1743 ;north patients: 544 ;south patients: 1248 ;dead: 39
Time: 300 days;normal people: 2983 ;shadow patients: 53 ;confirmed patients: 1921 ;north patients: 654 ;south patients: 1298 ;dead: 43
Time: 330 days;normal people: 2822 ;shadow patients: 48 ;confirmed patients: 2087 ;north patients: 783 ;south patients: 1330 ;dead: 43
Time: 360 days;normal people: 2632 ;shadow patients: 64 ;confirmed patients: 2257 ;north patients: 944 ;south patients: 1354 ;dead: 47
```

### 5.5.2 When area has quarantine and people who across the line must isolate 3 days:

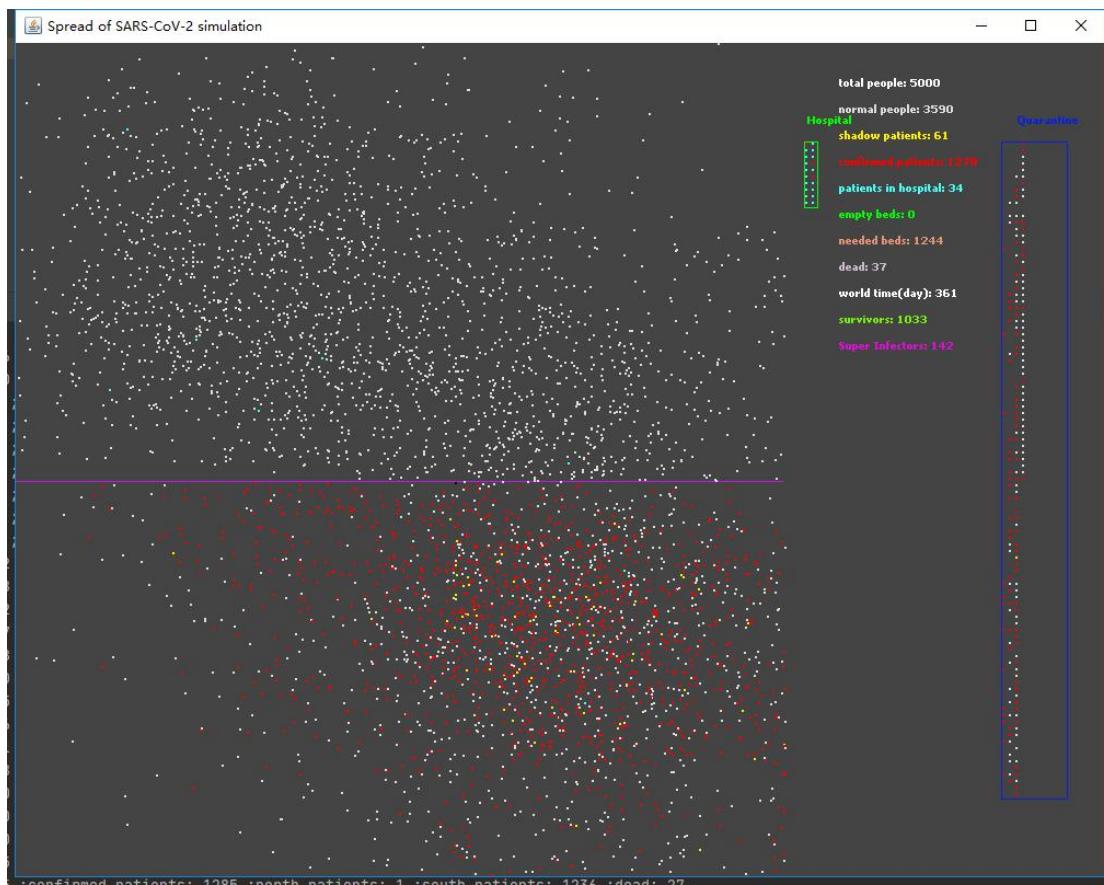


```

Time: 10 days;normal people: 4675 ;shadow patients: 178 ;confirmed patients: 147 ;north patients: 0 ;south patients: 301 ;dead: 0
Time: 20 days;normal people: 4359 ;shadow patients: 156 ;confirmed patients: 483 ;north patients: 0 ;south patients: 610 ;dead: 2
Time: 30 days;normal people: 4109 ;shadow patients: 136 ;confirmed patients: 748 ;north patients: 1 ;south patients: 845 ;dead: 7
Time: 40 days;normal people: 3956 ;shadow patients: 113 ;confirmed patients: 923 ;north patients: 4 ;south patients: 986 ;dead: 8
Time: 50 days;normal people: 3857 ;shadow patients: 79 ;confirmed patients: 1050 ;north patients: 7 ;south patients: 1068 ;dead: 14
Time: 60 days;normal people: 3788 ;shadow patients: 82 ;confirmed patients: 1115 ;north patients: 9 ;south patients: 1130 ;dead: 15
Time: 70 days;normal people: 3748 ;shadow patients: 59 ;confirmed patients: 1177 ;north patients: 11 ;south patients: 1159 ;dead: 16
Time: 80 days;normal people: 3699 ;shadow patients: 73 ;confirmed patients: 1210 ;north patients: 16 ;south patients: 1197 ;dead: 18
Time: 90 days;normal people: 3654 ;shadow patients: 74 ;confirmed patients: 1253 ;north patients: 18 ;south patients: 1233 ;dead: 19
Time: 100 days;normal people: 3631 ;shadow patients: 48 ;confirmed patients: 1301 ;north patients: 24 ;south patients: 1243 ;dead: 20
Time: 110 days;normal people: 3588 ;shadow patients: 71 ;confirmed patients: 1321 ;north patients: 43 ;south patients: 1260 ;dead: 20
Time: 120 days;normal people: 3549 ;shadow patients: 69 ;confirmed patients: 1362 ;north patients: 55 ;south patients: 1286 ;dead: 20
Time: 130 days;normal people: 3533 ;shadow patients: 69 ;confirmed patients: 1378 ;north patients: 68 ;south patients: 1283 ;dead: 20
Time: 140 days;normal people: 3489 ;shadow patients: 78 ;confirmed patients: 1413 ;north patients: 84 ;south patients: 1298 ;dead: 20
Time: 150 days;normal people: 3447 ;shadow patients: 66 ;confirmed patients: 1467 ;north patients: 97 ;south patients: 1322 ;dead: 20
Time: 160 days;normal people: 3371 ;shadow patients: 76 ;confirmed patients: 1533 ;north patients: 141 ;south patients: 1347 ;dead: 20
Time: 170 days;normal people: 3328 ;shadow patients: 72 ;confirmed patients: 1586 ;north patients: 181 ;south patients: 1351 ;dead: 22
Time: 180 days;normal people: 3266 ;shadow patients: 74 ;confirmed patients: 1638 ;north patients: 230 ;south patients: 1353 ;dead: 22
Time: 190 days;normal people: 3191 ;shadow patients: 93 ;confirmed patients: 1693 ;north patients: 267 ;south patients: 1385 ;dead: 23
Time: 200 days;normal people: 3135 ;shadow patients: 69 ;confirmed patients: 1772 ;north patients: 312 ;south patients: 1390 ;dead: 24
Time: 210 days;normal people: 3053 ;shadow patients: 82 ;confirmed patients: 1840 ;north patients: 367 ;south patients: 1417 ;dead: 25
Time: 220 days;normal people: 3003 ;shadow patients: 84 ;confirmed patients: 1888 ;north patients: 415 ;south patients: 1416 ;dead: 25
Time: 230 days;normal people: 2939 ;shadow patients: 88 ;confirmed patients: 1946 ;north patients: 455 ;south patients: 1426 ;dead: 27
Time: 240 days;normal people: 2900 ;shadow patients: 76 ;confirmed patients: 1996 ;north patients: 513 ;south patients: 1397 ;dead: 28
Time: 250 days;normal people: 2811 ;shadow patients: 101 ;confirmed patients: 2057 ;north patients: 570 ;south patients: 1420 ;dead: 31
Time: 260 days;normal people: 2749 ;shadow patients: 92 ;confirmed patients: 2125 ;north patients: 627 ;south patients: 1420 ;dead: 34
Time: 270 days;normal people: 2653 ;shadow patients: 95 ;confirmed patients: 2217 ;north patients: 687 ;south patients: 1446 ;dead: 35
Time: 280 days;normal people: 2565 ;shadow patients: 89 ;confirmed patients: 2308 ;north patients: 736 ;south patients: 1473 ;dead: 38
Time: 290 days;normal people: 2529 ;shadow patients: 72 ;confirmed patients: 2359 ;north patients: 777 ;south patients: 1463 ;dead: 40
Time: 300 days;normal people: 2467 ;shadow patients: 73 ;confirmed patients: 2417 ;north patients: 821 ;south patients: 1473 ;dead: 43
Time: 310 days;normal people: 2413 ;shadow patients: 79 ;confirmed patients: 2465 ;north patients: 865 ;south patients: 1472 ;dead: 43
Time: 320 days;normal people: 2358 ;shadow patients: 76 ;confirmed patients: 2521 ;north patients: 920 ;south patients: 1464 ;dead: 45
Time: 330 days;normal people: 2318 ;shadow patients: 67 ;confirmed patients: 2570 ;north patients: 949 ;south patients: 1468 ;dead: 45
Time: 340 days;normal people: 2266 ;shadow patients: 88 ;confirmed patients: 2598 ;north patients: 966 ;south patients: 1494 ;dead: 48
Time: 350 days;normal people: 2232 ;shadow patients: 66 ;confirmed patients: 2650 ;north patients: 995 ;south patients: 1488 ;dead: 52
Time: 360 days;normal people: 2195 ;shadow patients: 82 ;confirmed patients: 2670 ;north patients: 1018 ;south patients: 1492 ;dead: 53
Time: 370 days;normal people: 2162 ;shadow patients: 82 ;confirmed patients: 2703 ;north patients: 1038 ;south patients: 1502 ;dead: 53
Time: 380 days;normal people: 2146 ;shadow patients: 56 ;confirmed patients: 2743 ;north patients: 1047 ;south patients: 1505 ;dead: 55

```

### 5.5.3 When area has quarantine and people who across the line must isolate 7 days:



```

Time: 10 days;normal people: 4689 ;shadow patients: 166 ;confirmed patients: 145 ;north patients: 0 ;south patients: 282 ;dead: 0
Time: 20 days;normal people: 4385 ;shadow patients: 150 ;confirmed patients: 463 ;north patients: 0 ;south patients: 579 ;dead: 2
Time: 30 days;normal people: 4194 ;shadow patients: 99 ;confirmed patients: 699 ;north patients: 0 ;south patients: 758 ;dead: 8
Time: 40 days;normal people: 4078 ;shadow patients: 94 ;confirmed patients: 818 ;north patients: 0 ;south patients: 863 ;dead: 10
Time: 50 days;normal people: 3995 ;shadow patients: 87 ;confirmed patients: 906 ;north patients: 0 ;south patients: 947 ;dead: 12
Time: 60 days;normal people: 3935 ;shadow patients: 75 ;confirmed patients: 977 ;north patients: 0 ;south patients: 1005 ;dead: 13
Time: 70 days;normal people: 3872 ;shadow patients: 77 ;confirmed patients: 1037 ;north patients: 1 ;south patients: 1057 ;dead: 14
Time: 80 days;normal people: 3804 ;shadow patients: 79 ;confirmed patients: 1099 ;north patients: 0 ;south patients: 1109 ;dead: 18
Time: 90 days;normal people: 3769 ;shadow patients: 82 ;confirmed patients: 1131 ;north patients: 0 ;south patients: 1140 ;dead: 18
Time: 100 days;normal people: 3750 ;shadow patients: 62 ;confirmed patients: 1170 ;north patients: 0 ;south patients: 1152 ;dead: 18
Time: 110 days;normal people: 3718 ;shadow patients: 68 ;confirmed patients: 1196 ;north patients: 0 ;south patients: 1177 ;dead: 18
Time: 120 days;normal people: 3689 ;shadow patients: 72 ;confirmed patients: 1220 ;north patients: 0 ;south patients: 1205 ;dead: 19
Time: 130 days;normal people: 3658 ;shadow patients: 57 ;confirmed patients: 1264 ;north patients: 0 ;south patients: 1232 ;dead: 21
Time: 140 days;normal people: 3676 ;shadow patients: 58 ;confirmed patients: 1244 ;north patients: 1 ;south patients: 1214 ;dead: 22
Time: 150 days;normal people: 3664 ;shadow patients: 70 ;confirmed patients: 1244 ;north patients: 1 ;south patients: 1219 ;dead: 22
Time: 160 days;normal people: 3648 ;shadow patients: 55 ;confirmed patients: 1275 ;north patients: 1 ;south patients: 1228 ;dead: 22
Time: 170 days;normal people: 3644 ;shadow patients: 66 ;confirmed patients: 1266 ;north patients: 0 ;south patients: 1233 ;dead: 24
Time: 180 days;normal people: 3661 ;shadow patients: 51 ;confirmed patients: 1264 ;north patients: 0 ;south patients: 1221 ;dead: 24
Time: 190 days;normal people: 3644 ;shadow patients: 68 ;confirmed patients: 1262 ;north patients: 0 ;south patients: 1231 ;dead: 24
Time: 200 days;normal people: 3626 ;shadow patients: 60 ;confirmed patients: 1289 ;north patients: 1 ;south patients: 1243 ;dead: 25
Time: 210 days;normal people: 3626 ;shadow patients: 60 ;confirmed patients: 1289 ;north patients: 1 ;south patients: 1243 ;dead: 25
Time: 220 days;normal people: 3626 ;shadow patients: 60 ;confirmed patients: 1289 ;north patients: 1 ;south patients: 1243 ;dead: 25
Time: 230 days;normal people: 3633 ;shadow patients: 55 ;confirmed patients: 1285 ;north patients: 1 ;south patients: 1236 ;dead: 27
Time: 240 days;normal people: 3633 ;shadow patients: 55 ;confirmed patients: 1285 ;north patients: 1 ;south patients: 1236 ;dead: 27
Time: 250 days;normal people: 3633 ;shadow patients: 16 ;confirmed patients: 1323 ;north patients: 1 ;south patients: 1234 ;dead: 28
Time: 260 days;normal people: 3651 ;shadow patients: 51 ;confirmed patients: 1270 ;north patients: 1 ;south patients: 1218 ;dead: 28
Time: 270 days;normal people: 3647 ;shadow patients: 60 ;confirmed patients: 1265 ;north patients: 1 ;south patients: 1250 ;dead: 28
Time: 280 days;normal people: 3652 ;shadow patients: 54 ;confirmed patients: 1265 ;north patients: 1 ;south patients: 1218 ;dead: 29

```

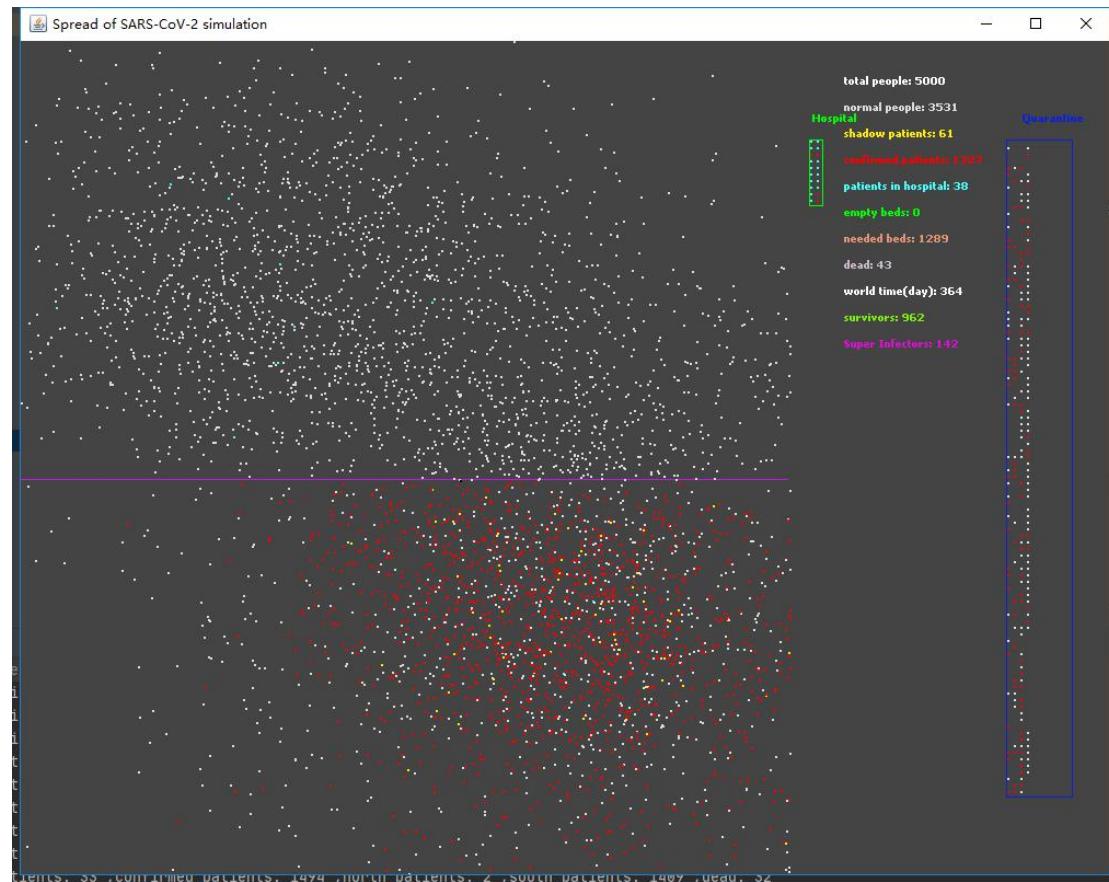
```

Time: 130 days;normal people: 3658 ;shadow patients: 57 ;confirmed patients: 1264 ;north patients: 0 ;south patients: 1232 ;dead: 21
Time: 140 days;normal people: 3676 ;shadow patients: 58 ;confirmed patients: 1244 ;north patients: 1 ;south patients: 1214 ;dead: 22
Time: 150 days;normal people: 3664 ;shadow patients: 70 ;confirmed patients: 1244 ;north patients: 1 ;south patients: 1219 ;dead: 22
Time: 160 days;normal people: 3648 ;shadow patients: 55 ;confirmed patients: 1275 ;north patients: 1 ;south patients: 1228 ;dead: 22
Time: 170 days;normal people: 3644 ;shadow patients: 66 ;confirmed patients: 1266 ;north patients: 0 ;south patients: 1233 ;dead: 24
Time: 180 days;normal people: 3661 ;shadow patients: 51 ;confirmed patients: 1264 ;north patients: 0 ;south patients: 1221 ;dead: 24
Time: 190 days;normal people: 3646 ;shadow patients: 68 ;confirmed patients: 1262 ;north patients: 0 ;south patients: 1231 ;dead: 24
Time: 200 days;normal people: 3626 ;shadow patients: 60 ;confirmed patients: 1289 ;north patients: 1 ;south patients: 1243 ;dead: 25
Time: 210 days;normal people: 3626 ;shadow patients: 60 ;confirmed patients: 1289 ;north patients: 1 ;south patients: 1243 ;dead: 25
Time: 220 days;normal people: 3626 ;shadow patients: 60 ;confirmed patients: 1289 ;north patients: 1 ;south patients: 1243 ;dead: 25
Time: 230 days;normal people: 3633 ;shadow patients: 55 ;confirmed patients: 1285 ;north patients: 1 ;south patients: 1236 ;dead: 27
Time: 240 days;normal people: 3633 ;shadow patients: 55 ;confirmed patients: 1285 ;north patients: 1 ;south patients: 1236 ;dead: 27
Time: 250 days;normal people: 3633 ;shadow patients: 16 ;confirmed patients: 1323 ;north patients: 1 ;south patients: 1234 ;dead: 28
Time: 260 days;normal people: 3651 ;shadow patients: 51 ;confirmed patients: 1270 ;north patients: 1 ;south patients: 1218 ;dead: 28
Time: 270 days;normal people: 3647 ;shadow patients: 68 ;confirmed patients: 1265 ;north patients: 1 ;south patients: 1230 ;dead: 28
Time: 280 days;normal people: 3652 ;shadow patients: 54 ;confirmed patients: 1265 ;north patients: 1 ;south patients: 1218 ;dead: 29
Time: 290 days;normal people: 3634 ;shadow patients: 69 ;confirmed patients: 1267 ;north patients: 0 ;south patients: 1235 ;dead: 30
Time: 300 days;normal people: 3607 ;shadow patients: 62 ;confirmed patients: 1301 ;north patients: 0 ;south patients: 1261 ;dead: 30
Time: 310 days;normal people: 3603 ;shadow patients: 55 ;confirmed patients: 1311 ;north patients: 0 ;south patients: 1261 ;dead: 31
Time: 320 days;normal people: 3622 ;shadow patients: 50 ;confirmed patients: 1296 ;north patients: 0 ;south patients: 1236 ;dead: 32
Time: 330 days;normal people: 3610 ;shadow patients: 70 ;confirmed patients: 1288 ;north patients: 1 ;south patients: 1244 ;dead: 32
Time: 340 days;normal people: 3597 ;shadow patients: 72 ;confirmed patients: 1298 ;north patients: 2 ;south patients: 1252 ;dead: 33
Time: 350 days;normal people: 3583 ;shadow patients: 63 ;confirmed patients: 1320 ;north patients: 1 ;south patients: 1261 ;dead: 34
Time: 360 days;normal people: 3586 ;shadow patients: 69 ;confirmed patients: 1308 ;north patients: 1 ;south patients: 1253 ;dead: 37
Time: 370 days;normal people: 3578 ;shadow patients: 65 ;confirmed patients: 1320 ;north patients: 1 ;south patients: 1263 ;dead: 37
Time: 380 days;normal people: 3560 ;shadow patients: 59 ;confirmed patients: 1340 ;north patients: 2 ;south patients: 1271 ;dead: 41

```

Process finished with exit code 0

#### 5.5.4 When area has quarantine and people who across the line must isolate 14 days:



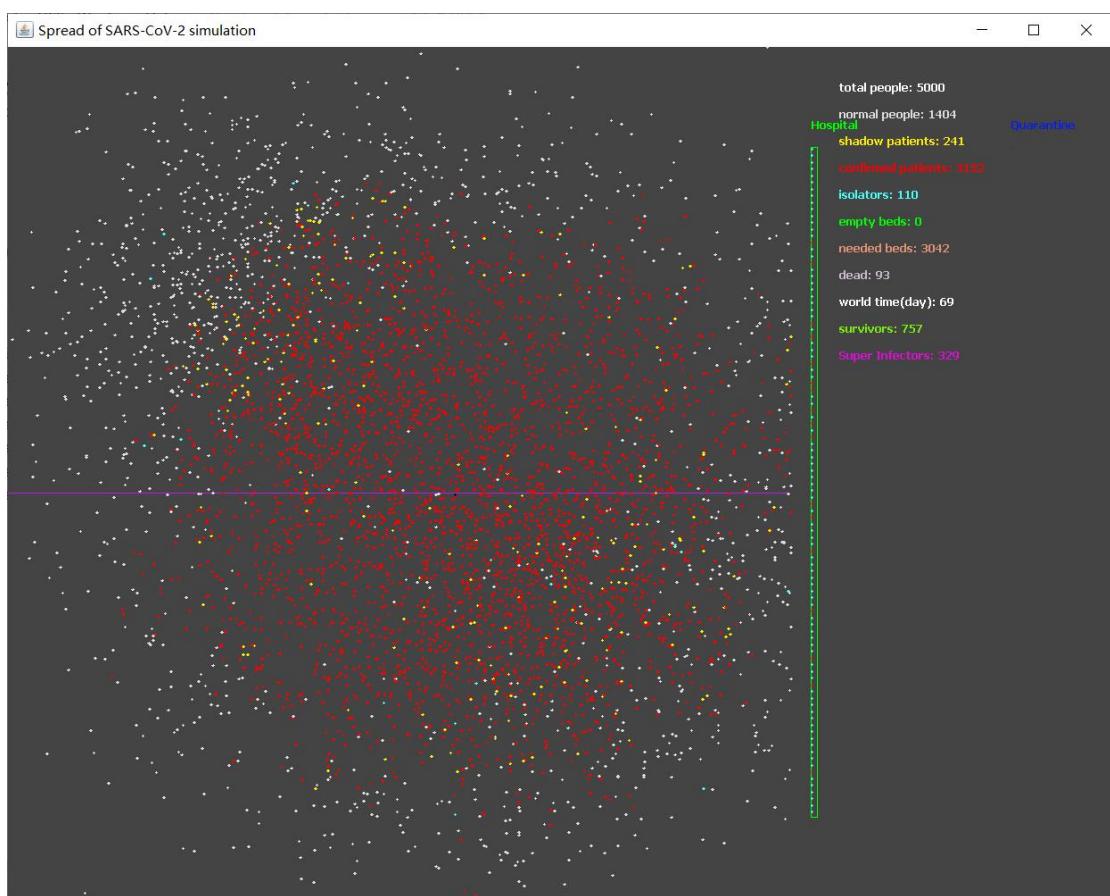
```

Time: 30 days;normal people: 4290 ;shadow patients: 141 ;confirmed patients: 563 ;north patients: 0 ;south patients: 675 ;dead: 6
Time: 60 days;normal people: 3862 ;shadow patients: 98 ;confirmed patients: 1025 ;north patients: 1 ;south patients: 1074 ;dead: 15
Time: 90 days;normal people: 3717 ;shadow patients: 52 ;confirmed patients: 1211 ;north patients: 0 ;south patients: 1196 ;dead: 20
Time: 120 days;normal people: 3626 ;shadow patients: 56 ;confirmed patients: 1296 ;north patients: 0 ;south patients: 1274 ;dead: 22
Time: 150 days;normal people: 3563 ;shadow patients: 44 ;confirmed patients: 1368 ;north patients: 1 ;south patients: 1321 ;dead: 25
Time: 180 days;normal people: 3514 ;shadow patients: 57 ;confirmed patients: 1403 ;north patients: 0 ;south patients: 1360 ;dead: 26
Time: 210 days;normal people: 3474 ;shadow patients: 42 ;confirmed patients: 1455 ;north patients: 2 ;south patients: 1382 ;dead: 29
Time: 240 days;normal people: 3424 ;shadow patients: 65 ;confirmed patients: 1481 ;north patients: 2 ;south patients: 1428 ;dead: 30
Time: 270 days;normal people: 3441 ;shadow patients: 33 ;confirmed patients: 1494 ;north patients: 2 ;south patients: 1409 ;dead: 32
Time: 300 days;normal people: 3447 ;shadow patients: 54 ;confirmed patients: 1462 ;north patients: 2 ;south patients: 1389 ;dead: 37
Time: 330 days;normal people: 3483 ;shadow patients: 64 ;confirmed patients: 1413 ;north patients: 0 ;south patients: 1347 ;dead: 40
Time: 360 days;normal people: 3539 ;shadow patients: 47 ;confirmed patients: 1371 ;north patients: 0 ;south patients: 1292 ;dead: 43

```

## 5.6 Other factors -- bed (hospital) count

### 5.6.1 there are 100 beds in hospital

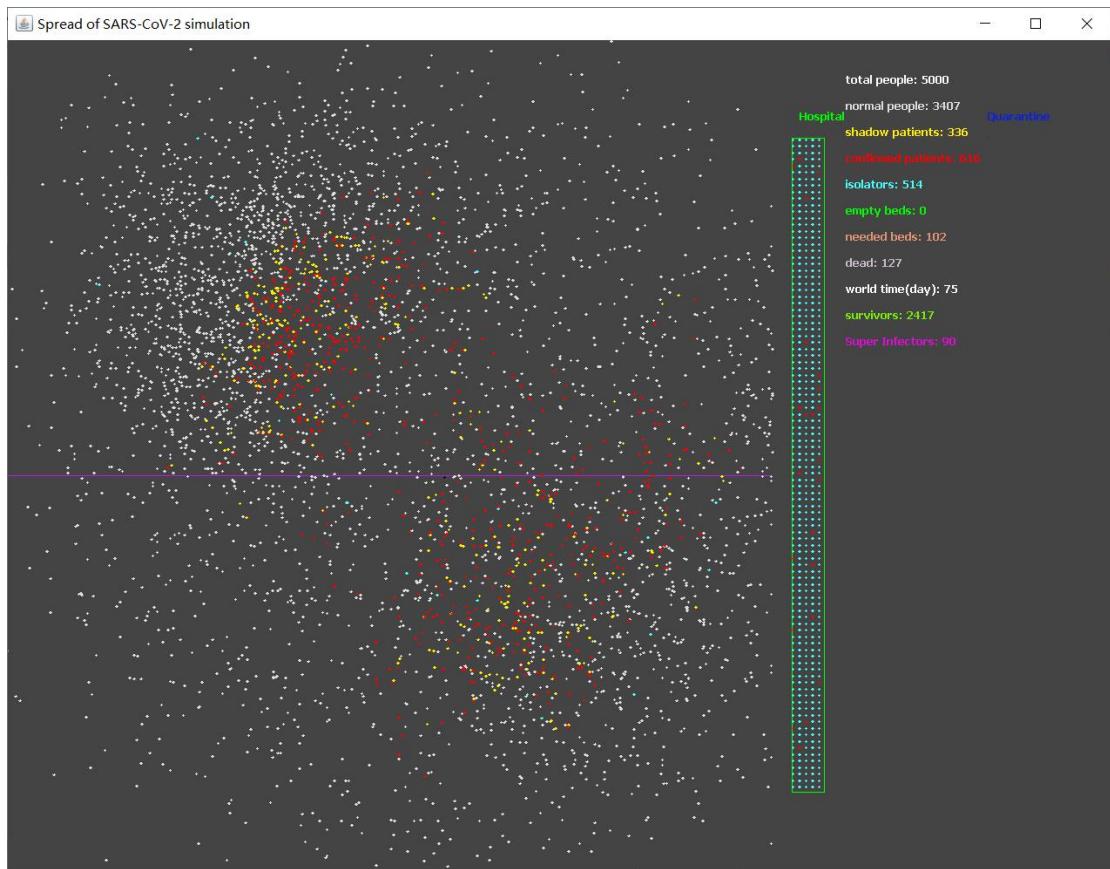


```

Time: 10 days;normal people: 3239 ;shadow patients: 878 ;confirmed patients: 883 ;dead: 0
Time: 20 days;normal people: 2109 ;shadow patients: 519 ;confirmed patients: 2358 ;dead: 14
Time: 30 days;normal people: 1578 ;shadow patients: 276 ;confirmed patients: 3097 ;dead: 49
Time: 40 days;normal people: 1454 ;shadow patients: 191 ;confirmed patients: 3286 ;dead: 69
Time: 50 days;normal people: 1464 ;shadow patients: 208 ;confirmed patients: 3250 ;dead: 78
Time: 60 days;normal people: 1425 ;shadow patients: 252 ;confirmed patients: 3240 ;dead: 83
Time: 70 days;normal people: 1397 ;shadow patients: 249 ;confirmed patients: 3261 ;dead: 93
Time: 80 days;normal people: 1346 ;shadow patients: 260 ;confirmed patients: 3291 ;dead: 103
Time: 90 days;normal people: 1303 ;shadow patients: 293 ;confirmed patients: 3288 ;dead: 116
Time: 100 days;normal people: 1291 ;shadow patients: 274 ;confirmed patients: 3302 ;dead: 133

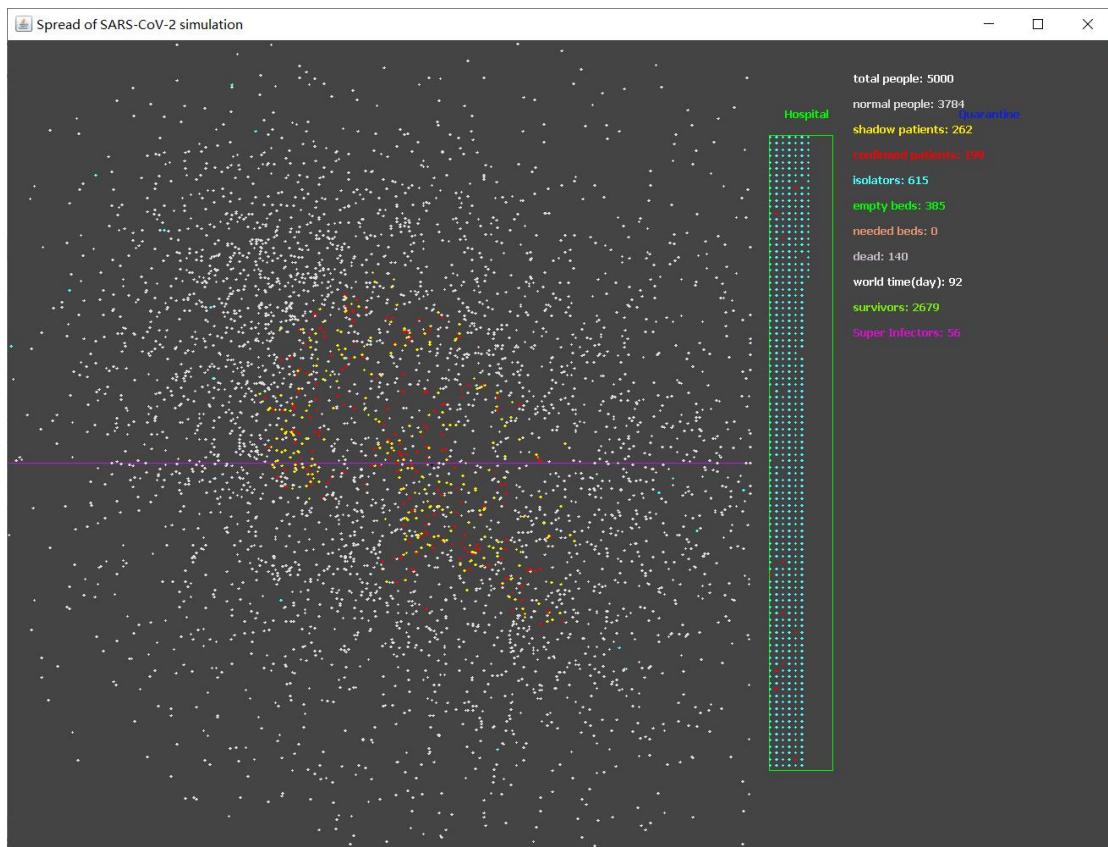
```

### 5.6.2 there are 500 beds in hospital



Time: 10 days;normal people: 3160 ;shadow patients: 885 ;confirmed patients: 955 ;dead: 0  
Time: 20 days;normal people: 2255 ;shadow patients: 359 ;confirmed patients: 2364 ;dead: 22  
Time: 30 days;normal people: 2510 ;shadow patients: 324 ;confirmed patients: 2113 ;dead: 53  
Time: 40 days;normal people: 2979 ;shadow patients: 356 ;confirmed patients: 1598 ;dead: 67  
Time: 50 days;normal people: 3169 ;shadow patients: 345 ;confirmed patients: 1402 ;dead: 84  
Time: 60 days;normal people: 3332 ;shadow patients: 322 ;confirmed patients: 1247 ;dead: 99  
Time: 70 days;normal people: 3471 ;shadow patients: 318 ;confirmed patients: 1094 ;dead: 117  
Time: 80 days;normal people: 3432 ;shadow patients: 314 ;confirmed patients: 1121 ;dead: 133  
Time: 90 days;normal people: 3497 ;shadow patients: 302 ;confirmed patients: 1056 ;dead: 145  
Time: 100 days;normal people: 3464 ;shadow patients: 320 ;confirmed patients: 1061 ;dead: 155

### 5.6.3 there are 1000 beds in hospital



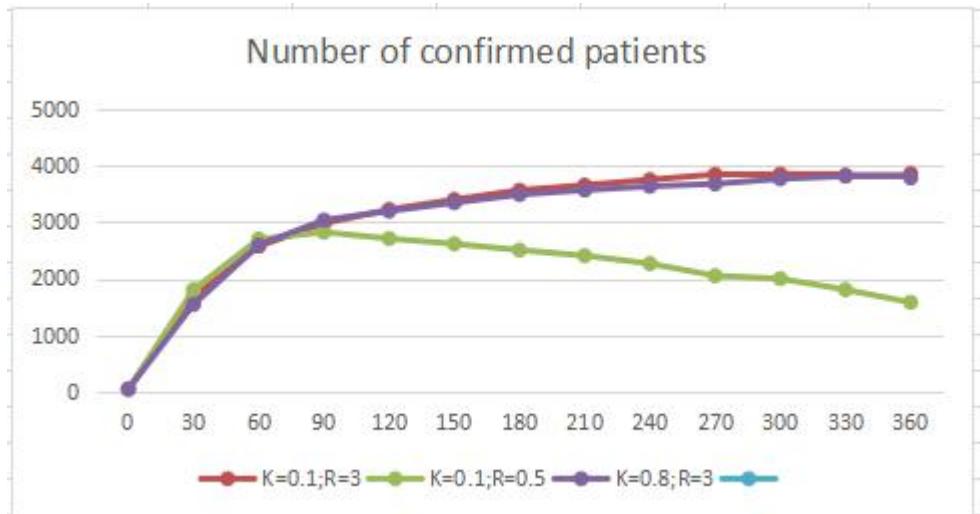
```
Time: 10 days;normal people: 3206 ;shadow patients: 933 ;confirmed patients: 861 ;dead: 0
Time: 20 days;normal people: 2235 ;shadow patients: 433 ;confirmed patients: 2314 ;dead: 18
Time: 30 days;normal people: 2968 ;shadow patients: 332 ;confirmed patients: 1644 ;dead: 56
Time: 40 days;normal people: 3510 ;shadow patients: 275 ;confirmed patients: 1139 ;dead: 76
Time: 50 days;normal people: 3745 ;shadow patients: 216 ;confirmed patients: 945 ;dead: 94
Time: 60 days;normal people: 3908 ;shadow patients: 195 ;confirmed patients: 792 ;dead: 105
Time: 70 days;normal people: 3925 ;shadow patients: 194 ;confirmed patients: 765 ;dead: 116
Time: 80 days;normal people: 3937 ;shadow patients: 205 ;confirmed patients: 732 ;dead: 126
Time: 90 days;normal people: 3807 ;shadow patients: 277 ;confirmed patients: 780 ;dead: 136
Time: 100 days;normal people: 3760 ;shadow patients: 216 ;confirmed patients: 876 ;dead: 148
```

## 6. Mathematical analysis/evidence

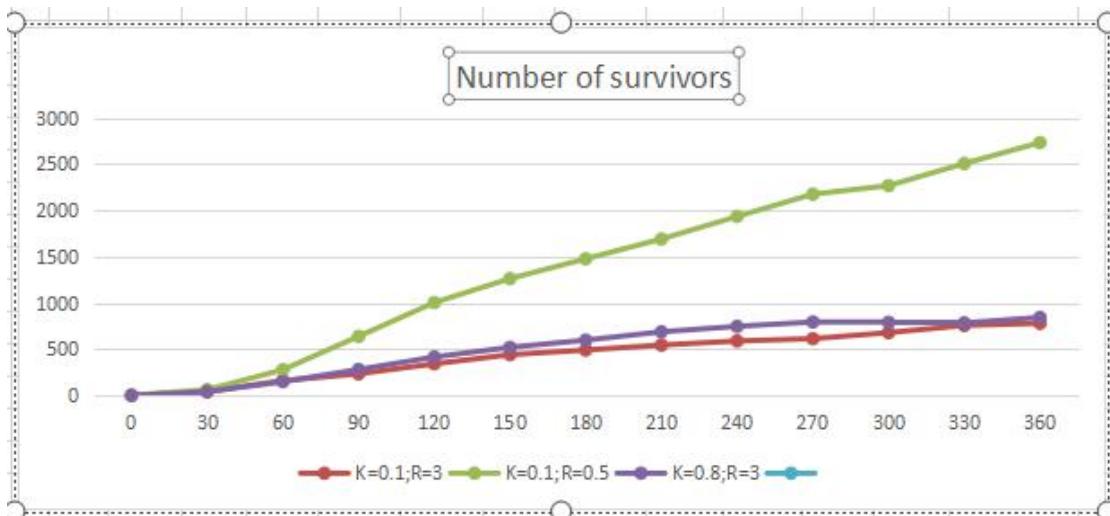
### 6.1 The k and R factors of the disease

In this section, we are going to compare the influence of different K and R factor for a virus. So, I simulate three couples of K,R. We can compare the number of confirmed patients, survivors (who recovered from this virus) and super spreaders in same time, so that, we can know the influence of different K and R values. Convert output data to follow tables:

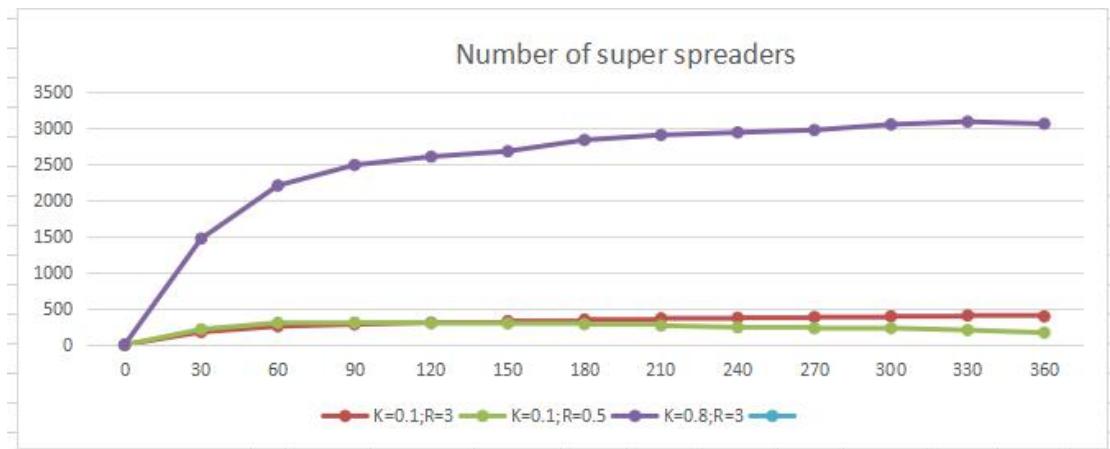
number of confirmed patients \time	0	30	60	90	120	150	180	210	240	270	300	330	360
K=0.1;R=3	50	1676	2572	2974	3218	3394	3559	3648	3745	3838	3843	3822	3851
K=0.1;R=0.5	50	1804	2695	2819	2706	2613	2503	2405	2264	2051	1998	1804	1580
K=0.8;R=3	50	1542	2591	3032	3191	3339	3482	3562	3628	3671	3760	3807	3777



number of survivors \time	0	30	60	90	120	150	180	210	240	270	300	330	360
K=0.1;R=3	0	41	159	233	341	440	490	544	588	613	678	756	779
K=0.1;R=0.5	0	61	277	638	1003	1262	1476	1690	1934	2175	2267	2506	2732
K=0.8;R=3	0	40	148	279	415	519	597	687	746	793	789	783	842



number of super spreaders \time	0	30	60	90	120	150	180	210	240	270	300	330	360
K=0.1;R=3	0	177	256	283	307	328	348	365	374	383	394	406	392
K=0.1;R=0.5	0	215	304	307	299	295	284	265	242	229	231	204	168
K=0.8;R=3	0	1467	2199	2482	2597	2672	2827	2896	2931	2964	3041	3080	3051



In the first,in order to know the influence of K value, we should compare ( $K=0.1,R=3$ ) and ( $K=0.8,R=3$ ).Obviously,only the number of super Spreaders have huge differences, When K values is bigger and the number of super Spreaders who can infect others easier would grow faster;Finally, it would keep a huge number which it is almost 79% of all confirmed patients.On the other hand, when K values is smaller, the number of super Spreaders is only 10% of all confirmed patients.

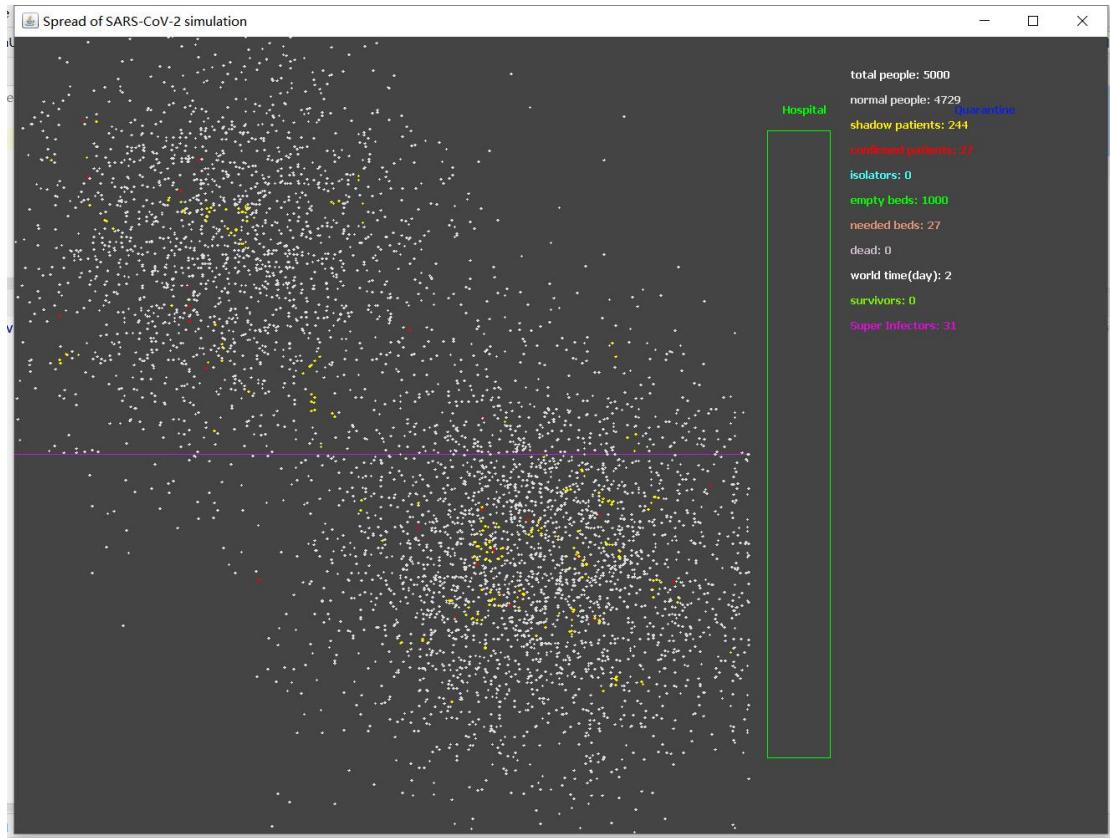
Secondly,In order to know the influence of R value,we should compare ( $K=0.1,R=3$ ) and ( $K=0.1,R=0.5$ ).Obviously, the number of survivors and confirmed patients in the same time both different. When  $R=3$ ,the number of confirmed patients would grow rapidly in first several months,then And then it stays very high until the end of the year;However, when  $R=0.5$ , the number of confirmed patients would grow rapidly in first several month same as the former, then The numbers of confirmed patients gradually decline, while the number of survivors increases rapidly. So,when R is smaller it would infect less person,and patients would recover quickly.

## 6.2 The population density

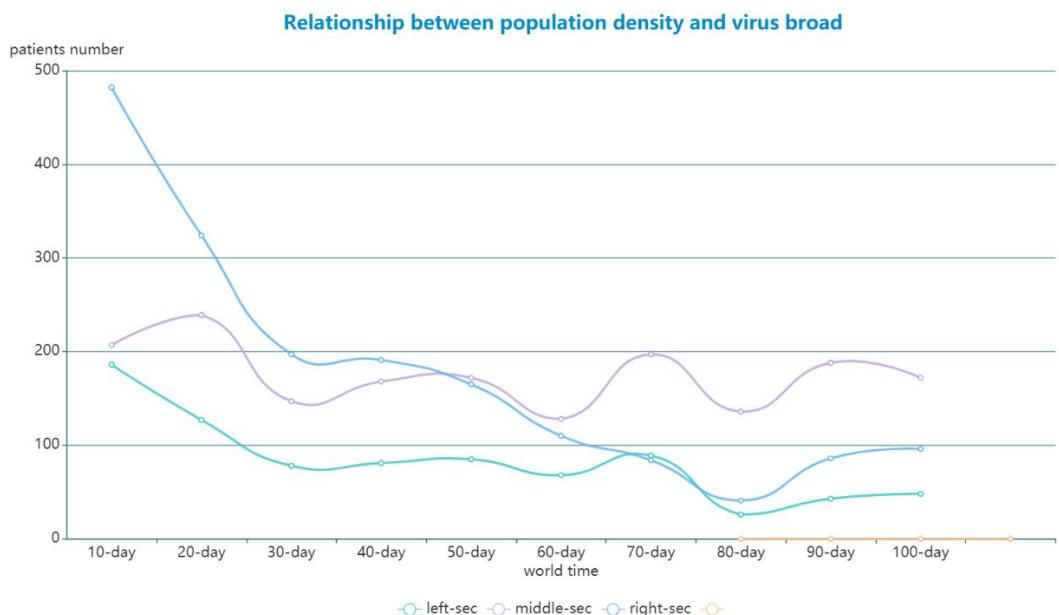
It is common to set distribution of people in this city by Gaussian distribution, the implementation of Gaussian distribution is showing for following picture:

```
private static final Random randomGen = new Random();
/**
 * Gaussian distribution
 * u--mean value, sigma--standard deviation
 * StdX = (X-u)/sigma
 * X = sigma * StdX + u
 */
public static double stdGaussian(double sigma, double u) {
    double X = randomGen.nextGaussian();
    return sigma * X + u;
}
```

And for researching density of people relating to virus broad, we initialize people as two groups with Gaussian distribution, in the northwest and southeast like follow:



With time passing, people will move randomly, most will move towards center of city, resulting in density of middle section will become higher than that of left section and right section, finally we can research these three sections' patients data for following table:

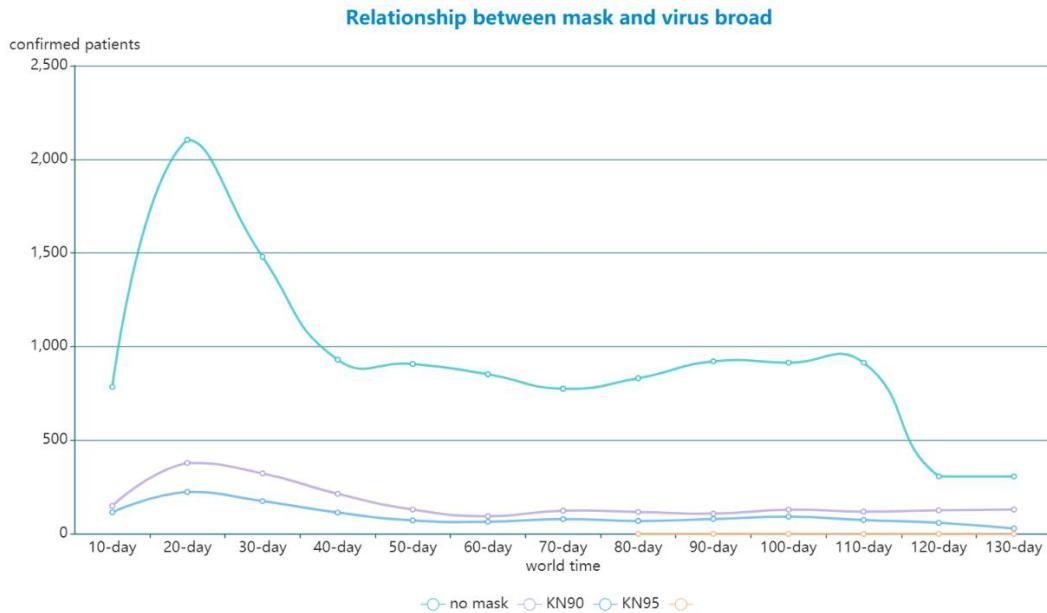


### 6.3 The usage and effectiveness of masks

Firstly, virus broad rate is related to type of mask, for instance, virus broads normally if nobody has mask, and block rate of KN90 mask is 90%, and that of KN95 is 95%. Besides, when

two people meeting, one person with mask and both with masks will have different results. Especially, one person with mask will be infected with 0.2 possibility, usually broad rate of virus is 0.8 possibility, so  $0.2 * 0.8$  is virus broad rate when just one with mask, while  $0.2 * 0.2$  is that of both with masks.

And according to output, we have following table:

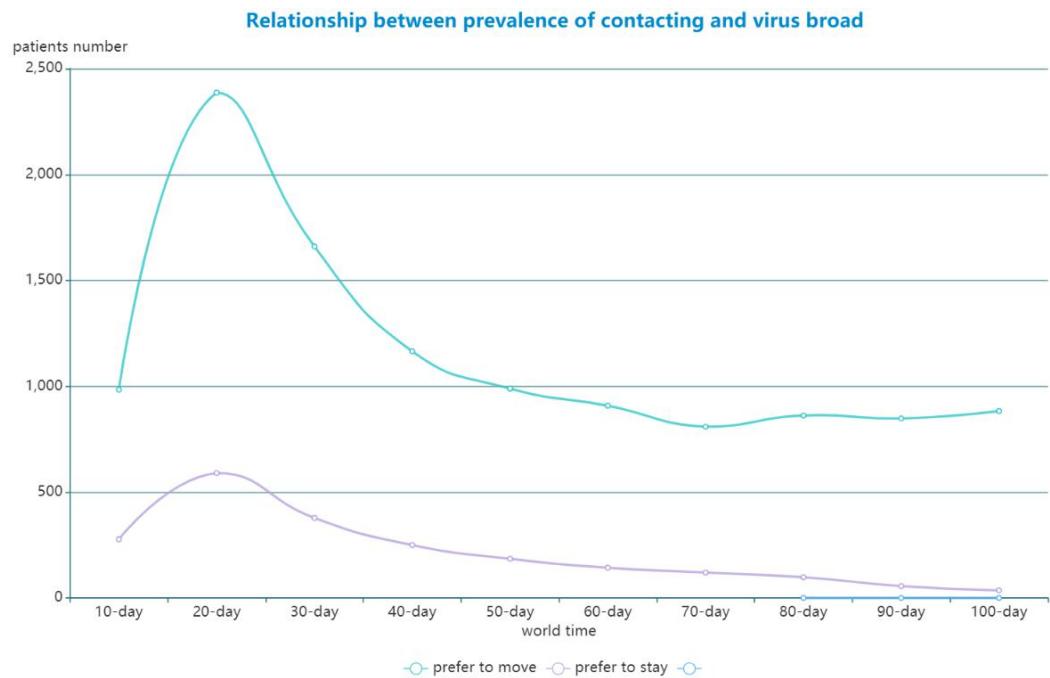


## 6.4 The prevalence of testing and contact tracing

We can express prevalence of contacting through updating mean of Gaussian distribution, especially, we define  $X$  matches Gaussian distribution ---  $N(u, \sigma)$ ,  $\sigma$  means affecting the distribution of the overall population mobility intention, while  $u$  is the axis of normal distribution to make more people prefer to flow or to be lazy (stay at home), so people prefer to move when  $stdGaussian$  is positive, and the range of contact intention is between -0.99 and 0.99. Its process is:

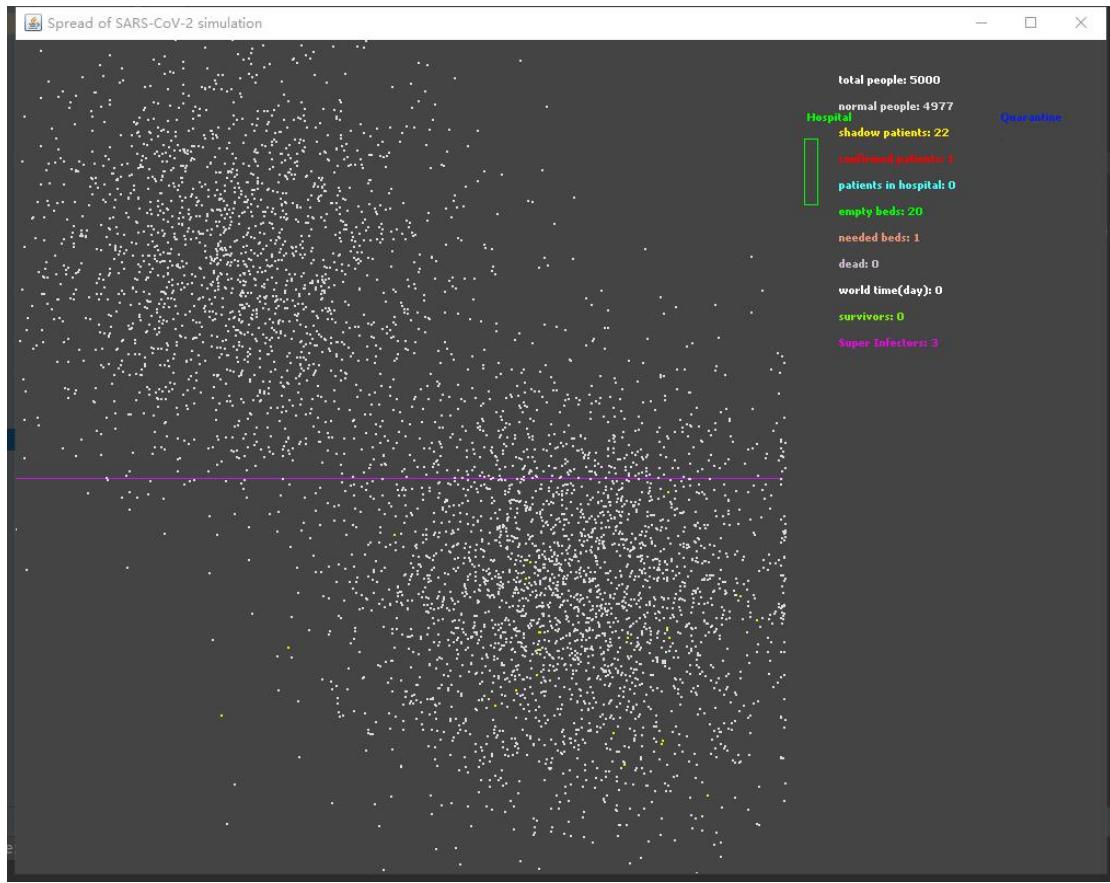
$$StdX = (X-u) / \sigma, X = \sigma * StdX + u.$$

And we can get following table:



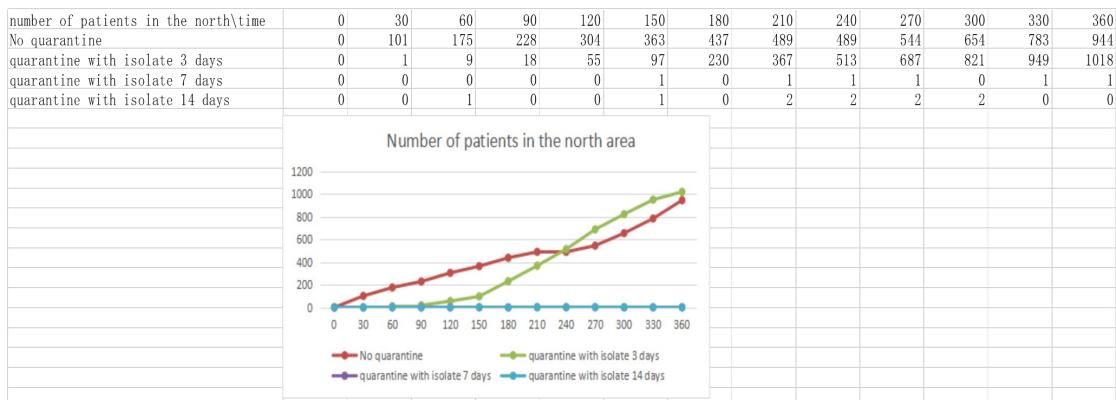
## 6.5 Any barriers to entry (including quarantining) into the subject area

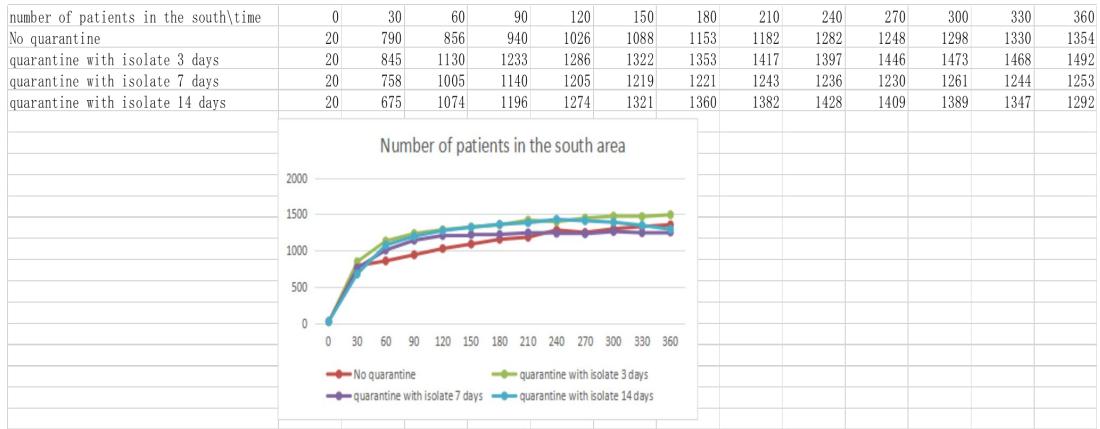
To the beginning, We divide the city as two area north and south. Those who cross the purple line will enter the quarantine zone and stay enough time. Then we random select 20 people in the south as shadow patients.



Then, we set the Factors.Quarantine\_BED\_COUNT = 0 (no quarantine),  
 Factors.Quarantine\_BED\_COUNT = 1000 and Factors.Quarantine\_WAIT\_TIME=30 (means area has quarantine and people who across the line must isolate 3 days),  
 Factors.Quarantine\_BED\_COUNT = 1000 and Factors.Quarantine\_WAIT\_TIME=70 (means area has quarantine and people who across the line must isolate 7 days),  
 Factors.Quarantine\_BED\_COUNT = 1000 and Factors.Quarantine\_WAIT\_TIME=140 (means area has quarantine and people who across the line must isolate 14 days), respectively.

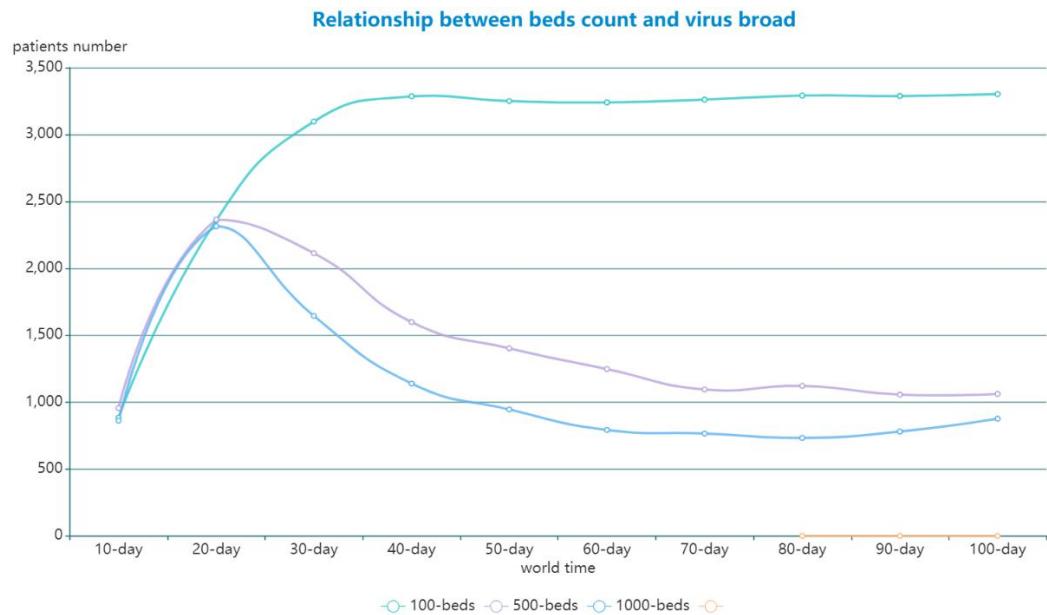
Finally, we convert the output data to follow tables:





## 6.6 Other factors -- bed (hospital) count

Patients are received by hospitals after passing received time (a period), and they will be isolated in hospital until all beds are full, while the rest of patients will exist among mass, so the number of beds in hospital is related to virus spread. And when patients are cured or dead, their beds will become empty offering for next patients. For this experiment, we research 100, 500, 1000 beds offered in hospital, and get following table:



## 7.conclusion

### 7.1 The k and R factors of the disease

According to the chart and output data, we can figure out that when K is bigger the ratio of super spreaders to normal patients would increase.

When R is become bigger, this virus would infect more person and patients would more slowly.

## **7.2 The population density**

It is clear to see initially patients are produced mostly in left section and right section where majority gathering. Later with people moving, middle section has the most patients than other sections, which means virus always breaks out mostly in high density places. Overall, virus can move to middle section where people gathering finally from two sides where people gathering at first, and finally virus reduces obviously in two sides section.

## **7.3 The usage and effectiveness of masks**

We define the number of confirmed patients as the number of virus showed in this world, we can see obviously these three situations showing confirmed patients will reduce because some has cured and others have died, but if people do not wear masks, virus will break out clearly and affect thousand of people in short term (about 20 days). On the other hand, different types of masks have different virus-blocked rates, obviously both KN90 and KN95 have clear curative effect, certainly if people choose to wear normal mask which belongs to clothes, they also cannot prevent virus.

## **7.4 The prevalence of testing and contact tracing**

It is clear to see virus spread easier in flowing population than stopping population, in other words, if people always move and contact with each other, they will infect or be infected by others easily, while if people tend to stay at home which means they hardly contact with others, they certainly will be infected with less possibility.

## **7.5 Any barriers to entry (including quarantining) into the subject area**

Apparently, no quarantine can't stop the spread of virus; quarantine with isolate 3 days can effectively protect north people in first 60 days,yet as time passed, more and more north people would be infected. quarantine with isolate 7 days and 14 days, both of them, can stop the virus spread to north area in one years.But quarantine with isolate 7 days can leave people more freedom time.In the conclusion, area quarantine with isolate 7 days can effectively stop the spread of the epidemic.

## **7.6 Other factors -- bed(hospital) count**

According to graph, we can see if there are few beds in hospital for quarantine, it will not solve problems of virus, while with the number of beds increasing, virus protection has clearer affection. But from user interface, we can see only for 1000 beds, there are some empty beds returned, which means big amount of beds in hospital can show affection of cure, and most

patients will wander in the city if hospital has fewer beds. On the other hand, it is also obvious to see that bed count factor cannot eliminate virus, because virus must broad among mass once one patient exist in public, so expanding bed count can just relieve but not to solve.

## 8.Unit test

The screenshot shows the IntelliJ IDEA interface during a unit test run. The top status bar indicates "Tests passed: 9 of 9 tests – 657 ms". The left sidebar lists the test classes and methods, each with a green checkmark indicating success. The right panel displays the command line output of the coverage runner, including the Java executable path, coverage sampling details, and class transformation time. It concludes with "Process finished with exit code 0".

Test Class	Method	Time (ms)
<default package>		657 ms
PersonTest	CureUpdateTest	179 ms
	beInfected	169 ms
	getDistanceTest	0 ms
	UpdateDeath	1 ms
	actionTest	0 ms
	QuarantineTest	7 ms
PopulationTest		2 ms
	getPeopleSize	1 ms
MainTest		1 ms
	InitTest	474 ms
MathUtilTest		474 ms
	stdGaussian	3 ms
		3 ms

