

Program Structure & Algorithms

Fall 2020

Team – 7

Respiratory Virus Simulation

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1. Introduction

A pandemic is sweeping the world over the past 2020. And the culprit is a novel coronavirus named COVID-19. Until now, over 67 million people being tested positive and over 14 million in the US. As it comes to winter, cases surging in most of the states which causes significant pressure on health care services.

The federal government came up with several proposals include face covering in public area, keep at least 6 feet for social distancing and curfew at 10 pm in some of the states. Each one of them has different effect of reducing the transmission of diseases. The integration of them all might on the positive side of mitigating the transmission of COVID-19. But these are assumption with no demanded proof. Millions of scientists over the world are working on finding an effective way of controlling the pandemic.

In order to better understand this worst public health event over the past century, we come up with a new way of making the whole researching process easier by simulating the transmission route graphically. It includes three processes, mathematical modeling, design algorithm and implementation and analysis.

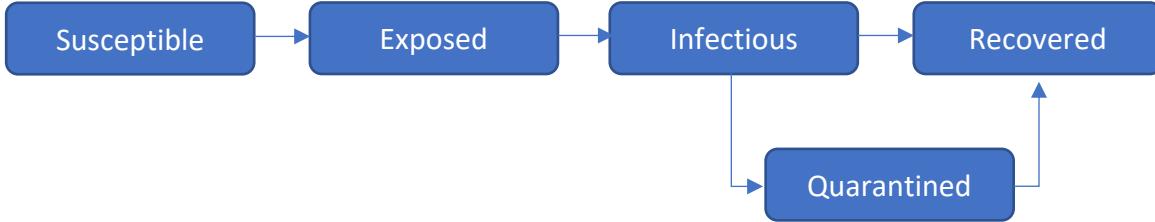
2. Aim of the Project

Simulate the transmission pattern of COVID-19 in order to find the effect of each measures include applying face covering, social distancing and quarantine in order to reduce the R value (Basic Reproduction Number).

3. Complete project detail

3.1 Model

The optimized SEIR model as the basic transmission model to simulate the spreading of diseases. The general SEIR model described down below:



We proposed an optimized SEIR model(van den Driessche, Pauline, 2017) which takes the rate of face covering, social distancing and quarantine status of the target city into account. Generally, when related symptoms comes out, he would be marked as susceptible. Some of them will be categorized as exposed because of contact with another patient who already tested positive. There is a probability he becomes positive marked as infectious.

$$\begin{aligned}
 S &= -\frac{S}{N} \left(\gamma \beta I + \frac{1 - (18.19 \ln(d) + 43.276)E}{100} \right) + (1 - M_{red} + M_{cov} + M_{ava})R_0 \\
 E &= \frac{S}{N} \left(\gamma \beta I + \frac{1 - (18.19 \ln(d) + 43.276)E}{100} \right) + (1 - M_{red} + M_{cov} + M_{ava})R_0 - \alpha E \\
 I &= \alpha E - \gamma I \\
 R &= \gamma I \\
 Q &= -\lambda Q + \rho S \\
 N &= S + E + I + R + Q
 \end{aligned}$$

S —number of Susceptible persons

E —number of Exposed persons

I —number of Infectious persons

R —number of Recovered persons

Q —number of Quarantined persons

β —probability of infected person transmitting to another person

d —distance between two persons

γ —probability of infected person becoming recovered

α —probability of exposed person becoming infected

λ —probability of quarantined person becoming recovered

M_{red} —aerosol reduction rate

M_{cov} —mask coverage rate

M_{ava} —mask availability to the population rate

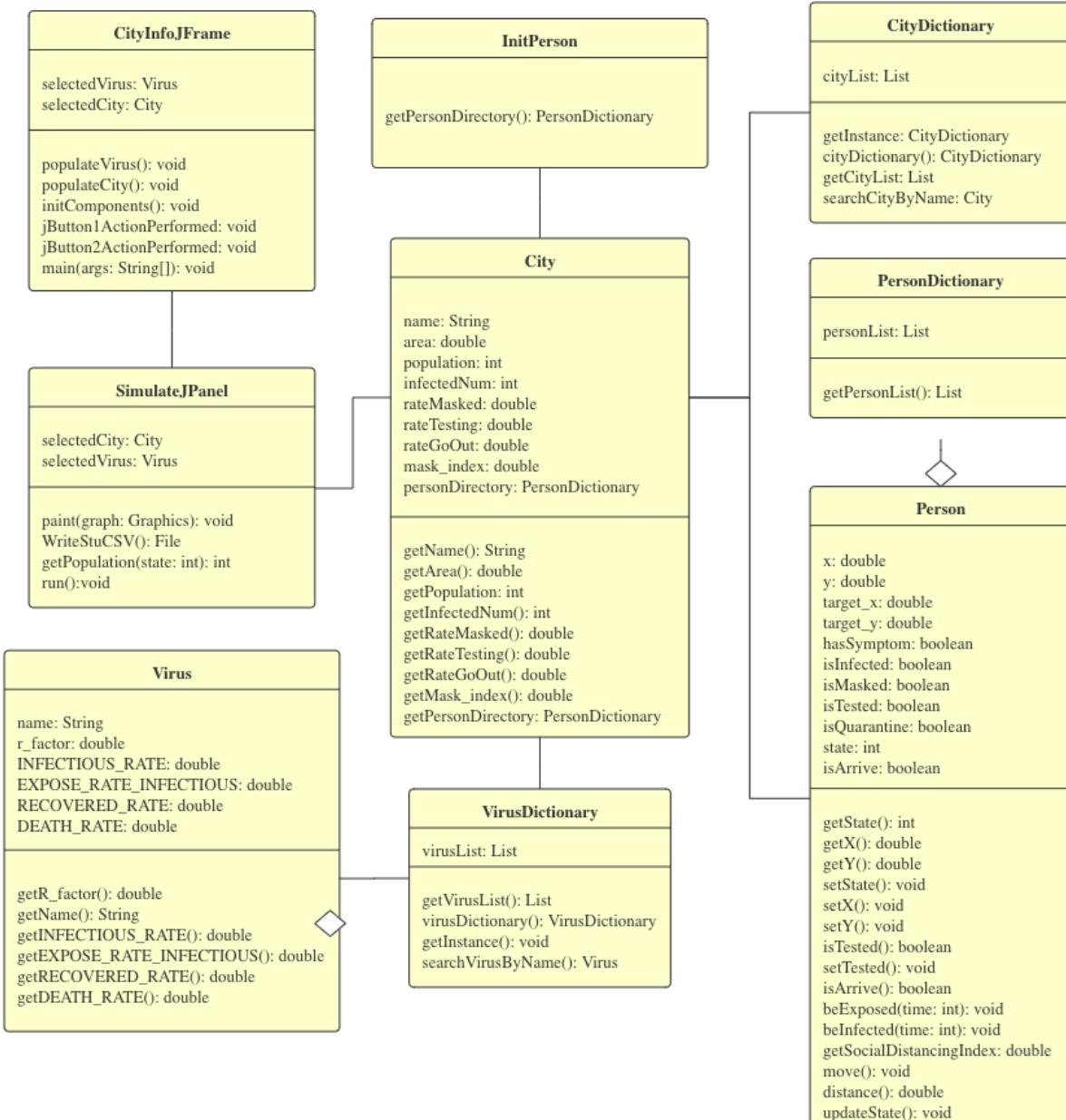
Here we define $M_{mas} = (1 - M_{red} + M_{cov} + M_{ava})R_0$ as Mask Index (Li, Tom, 2020) which represents the efficiency of taking masks. The greater the more efficient of face covering applies in this city.

$D_{sd} = \frac{1 - (18.19 \ln(d) + 43.276)E}{100}$ is defined as Social Distancing Index (Eikenberry, Steffen E, 2020)

which represents the effects of applying social distancing. The greater of parameter d the less of D_{sd} is. The less D_{sd} is the better effect it has as lower probability of getting infected when distance getting big enough.

3.2 Application structure

Class City is set as abstract type in order to be extended by several classes. Each one of them represent a different city and holds several properties including PersonList and VirusList.



3.3 Properties and factors

3.3.1 The K and R factors of the disease

R stands for Basic Reproduction Number. The less R is the less transmission rate the virus could be. Basically, every interference we put into our system is to reduce the transmission rate of the disease. In our application, we use R value as condition to make judgement of whether a person is exposed enough to be infected.

```
if (cityVariables.getSocialDistancingIndex(distance(person.getX(), person.getY())) < 0.25) {  
    if (CityVariables.MASK_INDEX * CityVariables.R_VALUE < 1) {  
        continue;  
    }  
}  
  
if(state == State.EXPOSED){  
    double distanceRandom = new Random().nextDouble();  
  
    for (Person person : personDictionary.getPersonList()) {  
  
        if (cityVariables.getSocialDistancingIndex(distance(person.getX(), person.getY())) < 0.25) {  
            if (CityVariables.MASK_INDEX * CityVariables.R_VALUE < 1) {  
                continue;  
            }  
        }  
        float possibility = 0;  
        if(person.getState() == 3) possibility = (float) (CityVariables.INFECTIOUS_RATE * CityVariables.MASK_INDEX *  
  
        // if the random number is less than the exposed possibility, make this person to be exposed  
        float random = new Random().nextFloat();  
        if (random < possibility) {  
            beInfected(SimulateJPanel.worldTime);  
            break;  
        }  
    }  
}
```

3.3.2 Social Distancing

We assume that applying social distancing could efficiently reduce the transmission rate of disease. In order to get proof of this assumption, we use perimeter Mask_Index as reference to measure the effect of taking masks.

```

    if (state == State.SUSCEPTIBLE) {

        double distanceRandom = new Random().nextDouble();
        for (Person person : personDictionary.getPersonList()) {

            if (cityVariables.getSocialDistancingIndex(distance(person.getX(), person.getY())) < 0.25) {
                if (CityVariables.MASK_INDEX * CityVariables.R_VALUE < 1) {
                    continue;
                }
            }
            if (distance(person.getX(), person.getY()) < CityVariables.SAFE_DISTANCE) {
                System.out.println("distance" + distance(person.getX(), person.getY()));
                continue;
            }

            float possibility = 0;
            if (person.getState() == 1) possibility = (float) (CityVariables.INFECTIOUS_RATE * CityVariables.MASK_INDEX

            // if the random number is less than the exposed possibility, make this person to be exposed
            float random = new Random().nextFloat();
            if (random < possibility) {
                this.beExposed(SimulateJPanel.worldTime);
                break;
            }
        }
    }
}

```

3.3.3 Barriers to entry into the quarantining area

Suppose a person satisfy two conditions: been tested and infected, then we set him as quarantined to block a certain group of people out of the other to simulate the real situation happens.

```

    }
} else if (state == State.INFECTIOUS) {
    float random = new Random().nextFloat();
    if (random < selectedVirus.getRECOVERED_RATE()) {
        this.state = State.RECOVERED;
    } else if (random >= selectedVirus.getRECOVERED_RATE() && random < (selectedVirus.getRECOVERED_RATE() + selectedVi
        this.state = State.DEATH;
    }

    if (isTested == true && state == State.INFECTIOUS) {
        this.state = State.QUARANTINED;
    }
}

```

3.3.4 The prevalence of testing and contact tracing

Used isTested variable to make judgement of whether the person is tested (Parikh, Sunil, 2020). If yes and result is positive, set them into Quarantine status.

```
if (state == State.SUSCEPTIBLE) {

    double distanceRandom = new Random().nextDouble();
    for (Person person : personDictionary.getPersonList()) {

        if (cityVariables.getSocialDistancingIndex(distance(person.getX(), person.getY())) < 0.25) {
            if (CityVariables.MASK_INDEX * CityVariables.R_VALUE < 1) {
                continue;
            }
        }
        if (distance(person.getX(), person.getY()) < CityVariables.SAFE_DISTANCE) {
            System.out.println("distance" + distance(person.getX(), person.getY()));
            continue;
        }

        float possibility = 0;
        if(person.getState() == 1) possibility = (float) (CityVariables.INFECTIOUS_RATE * CityVariables.MASK_INDEX);

        // if the random number is less than the exposed possibility, make this person to be exposed
        float random = new Random().nextFloat();
        if (random < possibility) {
            this.beExposed(SimulateJPanel.worldTime);
            break;
        }

        if (isTested == true && state == State.INFECTIOUS) {
            this.state = State.QUARANTINED;
        }
    }
}
```

3.3.4 Fatality rate

```
        }
    else if (state == State.INFECTIOUS) {
        float random = new Random().nextFloat();
        if (random < selectedVirus.getRECOVERED_RATE()) {
            this.state = State.RECOVERED;
        } else if (random >= selectedVirus.getRECOVERED_RATE() && random < (selectedVirus.getRECOVERED_RATE() + selectedVirus.getDEATH_RATE())) {
            this.state = State.DEATH;
        }

        if (isTested == true && state == State.INFECTIOUS) {
            this.state = State.QUARANTINED;
        }
    }
```

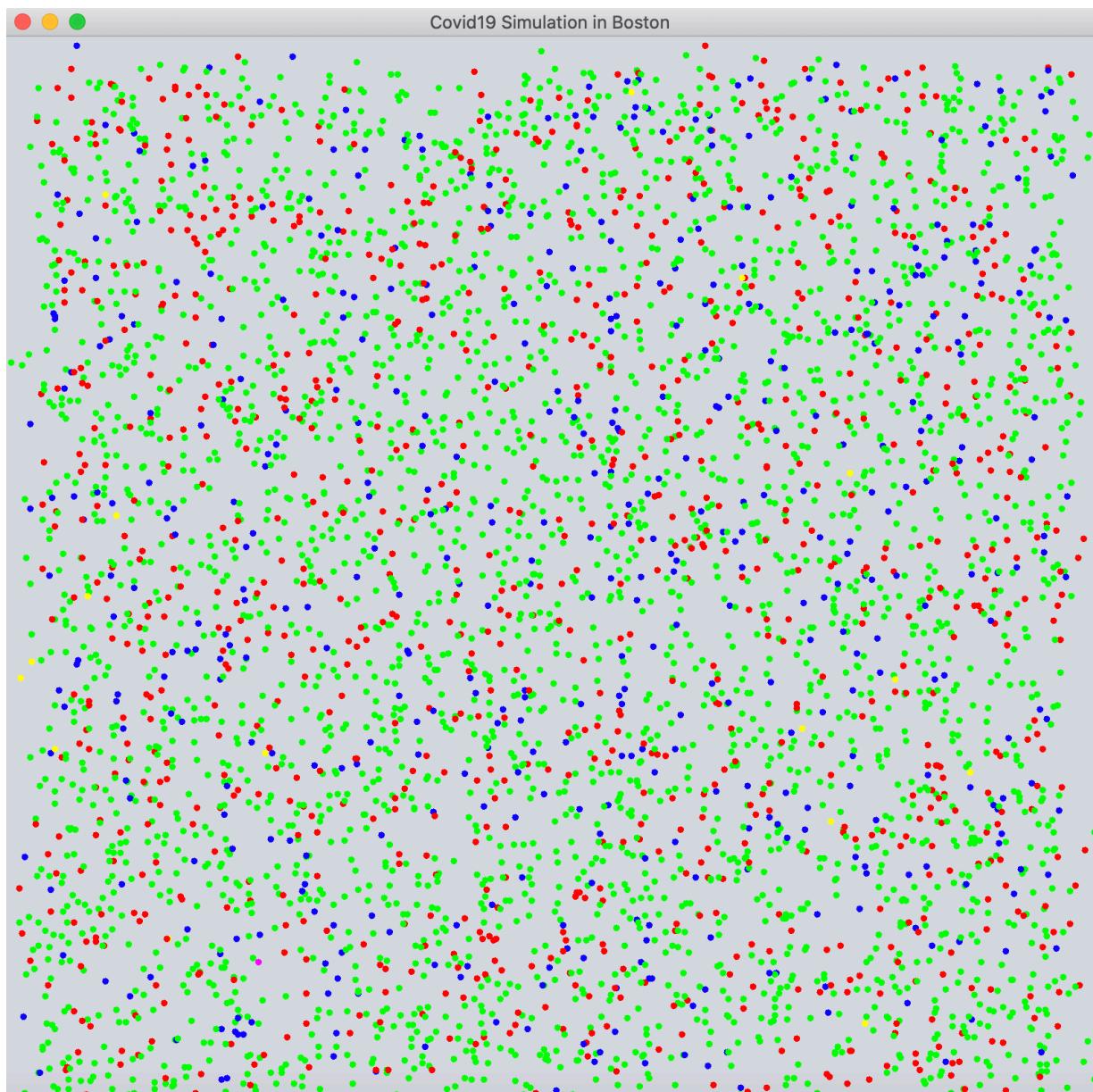
3.4 Output

Beside COVID-19, we also simulate the spreading of three other viruses with different factors. Those are SARS, Measles, Pertussis. Different virus has different factors, which we can see in the below table:

	R factor	Infectious Rate	Expose Rate Infectious	Recovered Rate	Death Rate
COVID-19	1.16	0.8	0.95	0.05	0.01
SARS	0.64	0.63	0.768	0.15	0.005
Measles	14	0.93	0.822	0.08	0.001
Pertussis	5.5	0.75	0.613	0.32	0.0005

After we simulated those four viruses in the same city, we can draw out some conclusion. First, let's see the result of those four viruses.

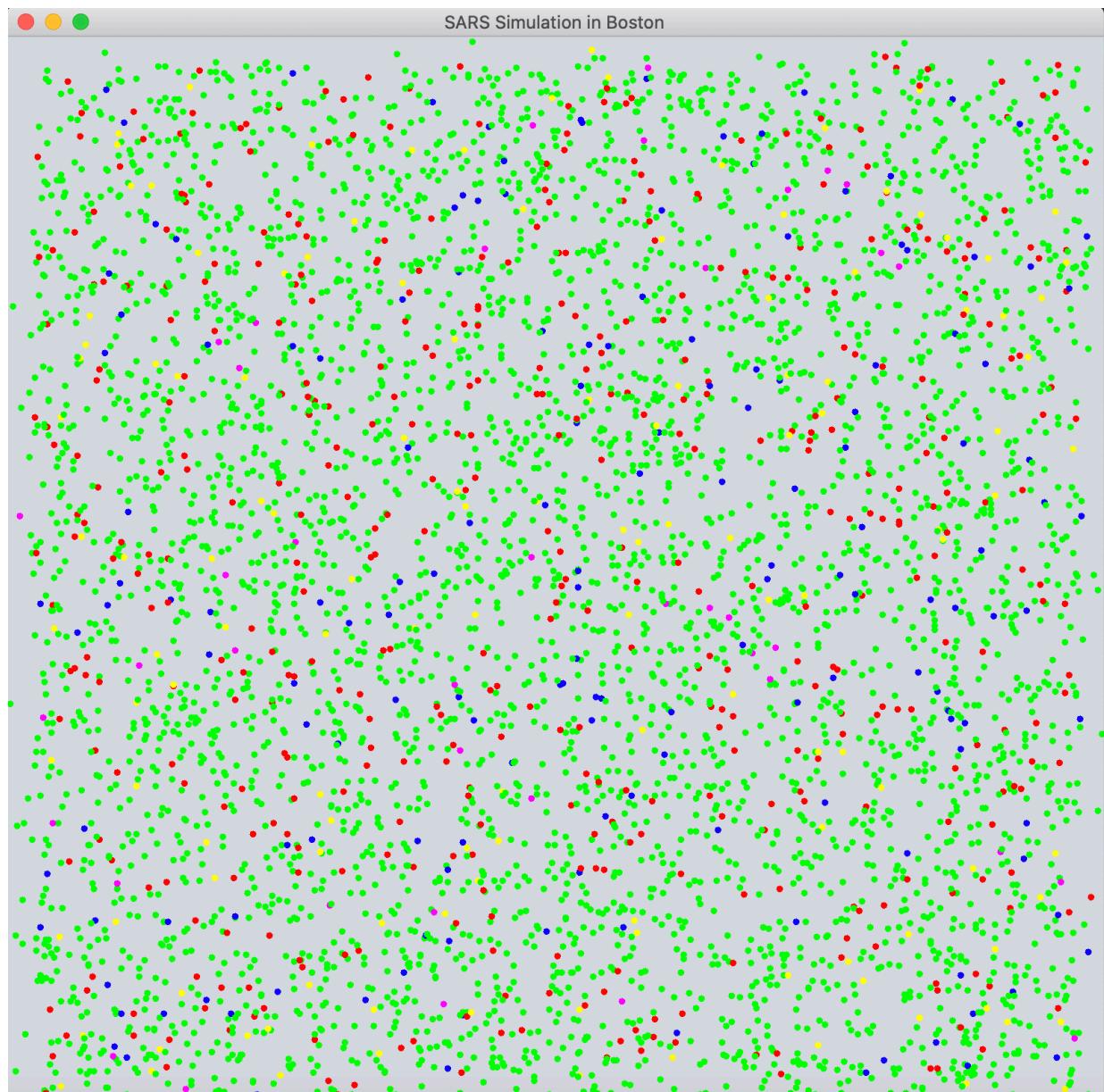
COVID-19 Simulation Result



Run: CityInfoJFrame

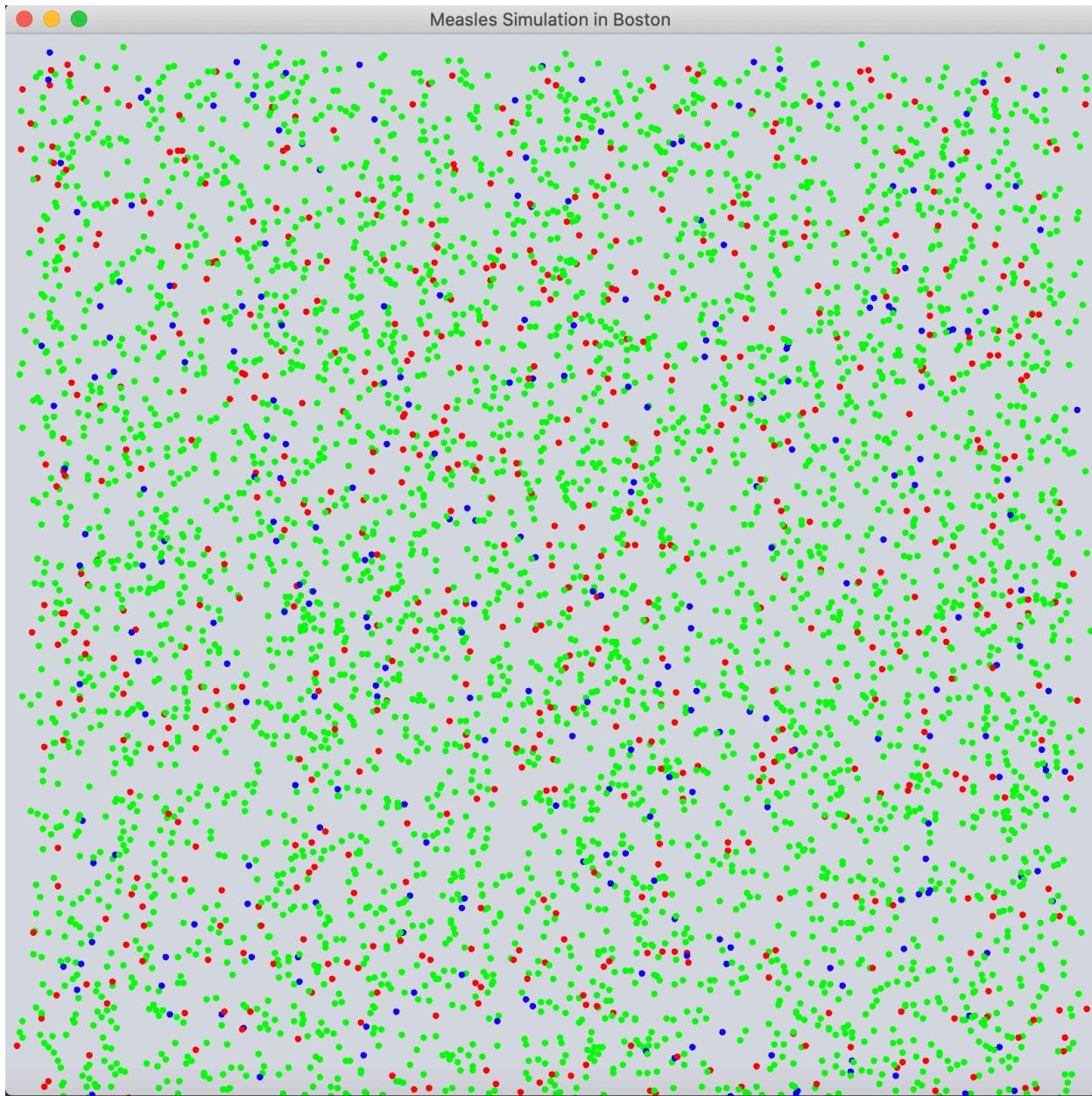
```
Recover: 0 Susceptible: 4900 Quarantined: 0 Exposed: 0 Infected: 100 Death: 0
Recover: 5 Susceptible: 4410 Quarantined: 29 Exposed: 491 Infected: 65 Death: 1
Recover: 5 Susceptible: 3875 Quarantined: 29 Exposed: 1025 Infected: 65 Death: 1
Recover: 8 Susceptible: 3516 Quarantined: 29 Exposed: 1324 Infected: 119 Death: 4
Recover: 8 Susceptible: 3187 Quarantined: 29 Exposed: 1073 Infected: 700 Death: 4
Recover: 8 Susceptible: 2815 Quarantined: 29 Exposed: 921 Infected: 1223 Death: 4
Recover: 48 Susceptible: 2483 Quarantined: 211 Exposed: 792 Infected: 1458 Death: 7
Recover: 99 Susceptible: 2113 Quarantined: 391 Exposed: 659 Infected: 1724 Death: 12
Recover: 184 Susceptible: 1778 Quarantined: 551 Exposed: 492 Infected: 1965 Death: 30
Recover: 305 Susceptible: 1479 Quarantined: 677 Exposed: 374 Infected: 2117 Death: 49
Recover: 444 Susceptible: 1181 Quarantined: 788 Exposed: 287 Infected: 2230 Death: 70
Recover: 601 Susceptible: 899 Quarantined: 868 Exposed: 279 Infected: 2258 Death: 95
Recover: 750 Susceptible: 728 Quarantined: 896 Exposed: 198 Infected: 2305 Death: 124
Recover: 919 Susceptible: 599 Quarantined: 925 Exposed: 142 Infected: 2268 Death: 147
Recover: 1069 Susceptible: 489 Quarantined: 934 Exposed: 117 Infected: 2213 Death: 177
Recover: 1220 Susceptible: 404 Quarantined: 928 Exposed: 93 Infected: 2163 Death: 191
Recover: 1359 Susceptible: 320 Quarantined: 919 Exposed: 91 Infected: 2101 Death: 210
Recover: 1519 Susceptible: 261 Quarantined: 887 Exposed: 67 Infected: 2041 Death: 225
Recover: 1658 Susceptible: 213 Quarantined: 874 Exposed: 51 Infected: 1962 Death: 242
Recover: 1810 Susceptible: 169 Quarantined: 842 Exposed: 50 Infected: 1863 Death: 266
Recover: 1937 Susceptible: 140 Quarantined: 818 Exposed: 35 Infected: 1787 Death: 282
Recover: 2072 Susceptible: 118 Quarantined: 787 Exposed: 25 Infected: 1706 Death: 292
Recover: 2194 Susceptible: 99 Quarantined: 756 Exposed: 20 Infected: 1628 Death: 303
Recover: 2298 Susceptible: 80 Quarantined: 730 Exposed: 20 Infected: 1550 Death: 320
Recover: 2406 Susceptible: 67 Quarantined: 702 Exposed: 13 Infected: 1476 Death: 336
Recover: 2505 Susceptible: 60 Quarantined: 672 Exposed: 8 Infected: 1400 Death: 355
Recover: 2618 Susceptible: 46 Quarantined: 647 Exposed: 14 Infected: 1311 Death: 364
Recover: 2709 Susceptible: 40 Quarantined: 615 Exposed: 7 Infected: 1251 Death: 378
Recover: 2811 Susceptible: 33 Quarantined: 590 Exposed: 7 Infected: 1169 Death: 390
Recover: 2902 Susceptible: 26 Quarantined: 566 Exposed: 7 Infected: 1098 Death: 401
Recover: 2992 Susceptible: 17 Quarantined: 534 Exposed: 9 Infected: 1035 Death: 413
Recover: 3070 Susceptible: 16 Quarantined: 506 Exposed: 1 Infected: 983 Death: 424
```

SARS Simulation Result



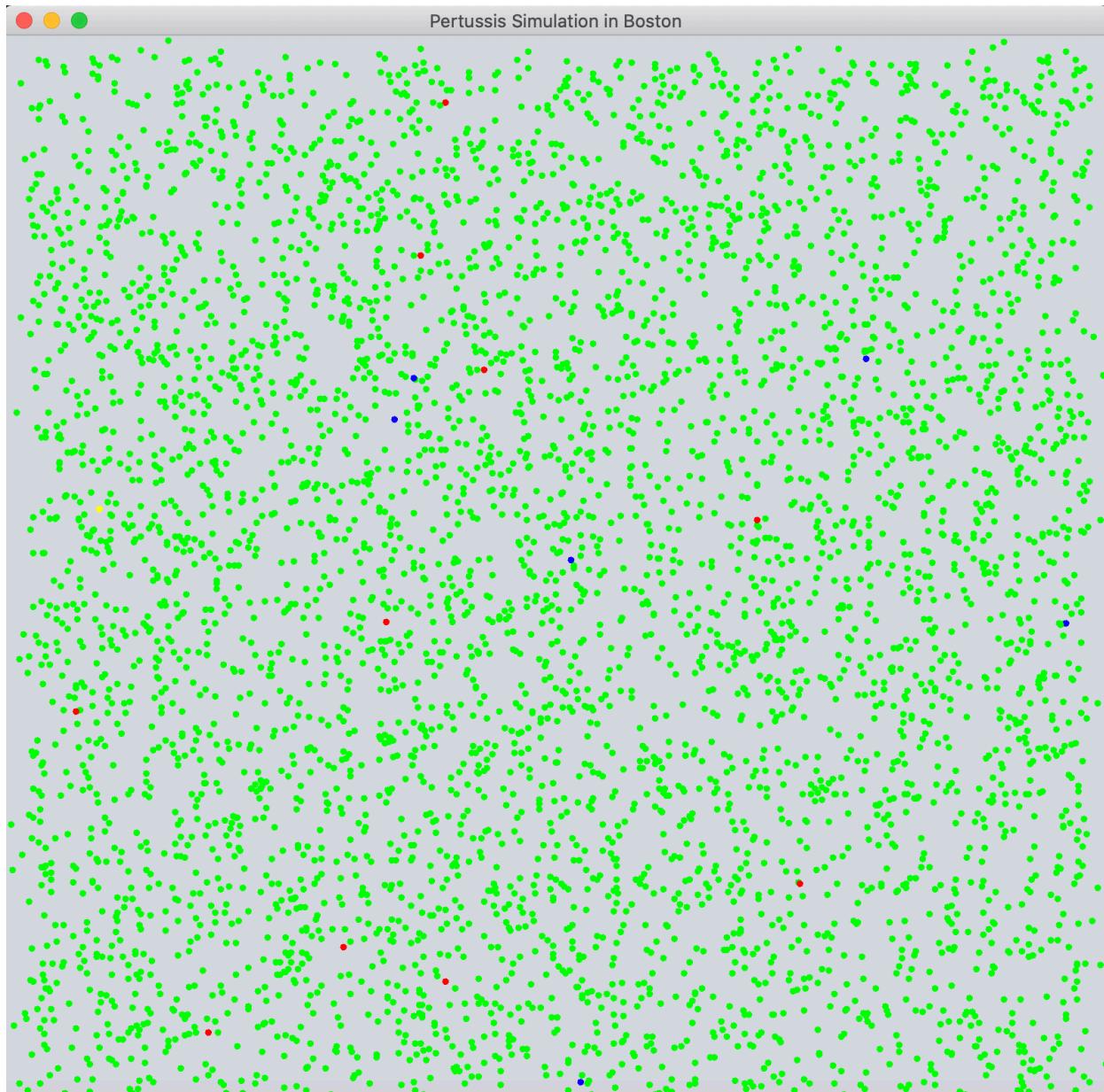
```
Recover: 0 Susceptible: 4900 Quarantined: 0 Exposed: 0 Infected: 100 Death: 0
Recover: 17 Susceptible: 4605 Quarantined: 25 Exposed: 295 Infected: 58 Death: 0
Recover: 17 Susceptible: 4240 Quarantined: 25 Exposed: 660 Infected: 58 Death: 0
Recover: 17 Susceptible: 3899 Quarantined: 25 Exposed: 1001 Infected: 58 Death: 0
Recover: 25 Susceptible: 3591 Quarantined: 22 Exposed: 1003 Infected: 359 Death: 0
Recover: 25 Susceptible: 3244 Quarantined: 22 Exposed: 1017 Infected: 692 Death: 0
Recover: 68 Susceptible: 2970 Quarantined: 80 Exposed: 1008 Infected: 874 Death: 0
Recover: 126 Susceptible: 2713 Quarantined: 169 Exposed: 917 Infected: 1074 Death: 1
Recover: 203 Susceptible: 2483 Quarantined: 250 Exposed: 807 Infected: 1253 Death: 4
Recover: 352 Susceptible: 2229 Quarantined: 324 Exposed: 727 Infected: 1361 Death: 7
Recover: 513 Susceptible: 2011 Quarantined: 387 Exposed: 640 Infected: 1436 Death: 12
Recover: 712 Susceptible: 1776 Quarantined: 448 Exposed: 541 Infected: 1505 Death: 18
Recover: 888 Susceptible: 1598 Quarantined: 493 Exposed: 464 Infected: 1532 Death: 25
Recover: 1182 Susceptible: 1368 Quarantined: 513 Exposed: 384 Infected: 1518 Death: 35
Recover: 1463 Susceptible: 1160 Quarantined: 523 Exposed: 344 Infected: 1469 Death: 41
Recover: 1769 Susceptible: 986 Quarantined: 500 Exposed: 316 Infected: 1379 Death: 49
Recover: 2042 Susceptible: 857 Quarantined: 484 Exposed: 230 Infected: 1333 Death: 54
Recover: 2295 Susceptible: 721 Quarantined: 482 Exposed: 221 Infected: 1221 Death: 59
Recover: 2555 Susceptible: 613 Quarantined: 436 Exposed: 181 Infected: 1153 Death: 62
Recover: 2811 Susceptible: 521 Quarantined: 407 Exposed: 160 Infected: 1035 Death: 66
Recover: 3003 Susceptible: 445 Quarantined: 398 Exposed: 121 Infected: 964 Death: 69
Recover: 3231 Susceptible: 372 Quarantined: 360 Exposed: 114 Infected: 846 Death: 77
Recover: 3397 Susceptible: 315 Quarantined: 321 Exposed: 95 Infected: 790 Death: 82
Recover: 3556 Susceptible: 277 Quarantined: 282 Exposed: 70 Infected: 732 Death: 83
Recover: 3717 Susceptible: 227 Quarantined: 250 Exposed: 81 Infected: 638 Death: 87
Recover: 3855 Susceptible: 193 Quarantined: 229 Exposed: 63 Infected: 569 Death: 91
Recover: 3992 Susceptible: 161 Quarantined: 189 Exposed: 58 Infected: 505 Death: 94
Recover: 4099 Susceptible: 134 Quarantined: 167 Exposed: 40 Infected: 464 Death: 95
Recover: 4186 Susceptible: 112 Quarantined: 151 Exposed: 37 Infected: 416 Death: 98
Recover: 4282 Susceptible: 104 Quarantined: 134 Exposed: 22 Infected: 359 Death: 99
Recover: 4359 Susceptible: 92 Quarantined: 123 Exposed: 18 Infected: 309 Death: 99
```

Measles Simulation Result



CityInfoJFrame						
↑	Recover:	0 Susceptible:	4900 Quarantined:	0 Exposed:	0 Infected:	100 Death: 0
↓	Recover:	7 Susceptible:	3193 Quarantined:	27 Exposed:	1709 Infected:	66 Death: 0
↶	Recover:	7 Susceptible:	2170 Quarantined:	27 Exposed:	2731 Infected:	66 Death: 0
↷	Recover:	7 Susceptible:	1451 Quarantined:	27 Exposed:	3450 Infected:	66 Death: 0
⤵	Recover:	7 Susceptible:	811 Quarantined:	27 Exposed:	4090 Infected:	66 Death: 0
⤶	Recover:	7 Susceptible:	248 Quarantined:	27 Exposed:	4652 Infected:	66 Death: 0
⤷	Recover:	17 Susceptible:	3 Quarantined:	22 Exposed:	3737 Infected:	1221 Death: 0
⤸	Recover:	17 Susceptible:	3 Quarantined:	22 Exposed:	2619 Infected:	2339 Death: 0
⤹	Recover:	17 Susceptible:	3 Quarantined:	22 Exposed:	1778 Infected:	3180 Death: 0
⤻	Recover:	17 Susceptible:	3 Quarantined:	22 Exposed:	1081 Infected:	3877 Death: 0
⤼	Recover:	17 Susceptible:	3 Quarantined:	22 Exposed:	502 Infected:	4456 Death: 0
⤽	Recover:	165 Susceptible:	3 Quarantined:	551 Exposed:	0 Infected:	4266 Death: 1
⤾	Recover:	751 Susceptible:	1 Quarantined:	1268 Exposed:	1 Infected:	2960 Death: 7
⤿	Recover:	1069 Susceptible:	1 Quarantined:	1176 Exposed:	0 Infected:	2744 Death: 9
⤻⤿	Recover:	1390 Susceptible:	1 Quarantined:	1071 Exposed:	0 Infected:	2524 Death: 14
⤻⤿	Recover:	1682 Susceptible:	1 Quarantined:	973 Exposed:	0 Infected:	2327 Death: 17
⤻⤿	Recover:	1929 Susceptible:	1 Quarantined:	890 Exposed:	0 Infected:	2160 Death: 19
⤻⤿	Recover:	2197 Susceptible:	1 Quarantined:	802 Exposed:	0 Infected:	1980 Death: 20
⤻⤿	Recover:	2449 Susceptible:	0 Quarantined:	736 Exposed:	1 Infected:	1793 Death: 20
⤻⤿	Recover:	2654 Susceptible:	0 Quarantined:	671 Exposed:	0 Infected:	1653 Death: 22
⤻⤿	Recover:	2857 Susceptible:	0 Quarantined:	611 Exposed:	0 Infected:	1507 Death: 25
⤻⤿	Recover:	3036 Susceptible:	0 Quarantined:	565 Exposed:	0 Infected:	1372 Death: 27
⤻⤿	Recover:	3220 Susceptible:	0 Quarantined:	523 Exposed:	0 Infected:	1230 Death: 27
⤻⤿	Recover:	3367 Susceptible:	0 Quarantined:	487 Exposed:	0 Infected:	1118 Death: 27
⤻⤿	Recover:	3480 Susceptible:	0 Quarantined:	459 Exposed:	0 Infected:	1034 Death: 27
⤻⤿	Recover:	3588 Susceptible:	0 Quarantined:	414 Exposed:	0 Infected:	970 Death: 28
⤻⤿	Recover:	3689 Susceptible:	0 Quarantined:	385 Exposed:	0 Infected:	896 Death: 30
⤻⤿	Recover:	3794 Susceptible:	0 Quarantined:	352 Exposed:	0 Infected:	824 Death: 30
⤻⤿	Recover:	3894 Susceptible:	0 Quarantined:	324 Exposed:	0 Infected:	749 Death: 33
⤻⤿	Recover:	3993 Susceptible:	0 Quarantined:	295 Exposed:	0 Infected:	678 Death: 34
⤻⤿	Recover:	4077 Susceptible:	0 Quarantined:	266 Exposed:	0 Infected:	621 Death: 36
⤻⤿	Recover:	4154 Susceptible:	0 Quarantined:	239 Exposed:	0 Infected:	571 Death: 36

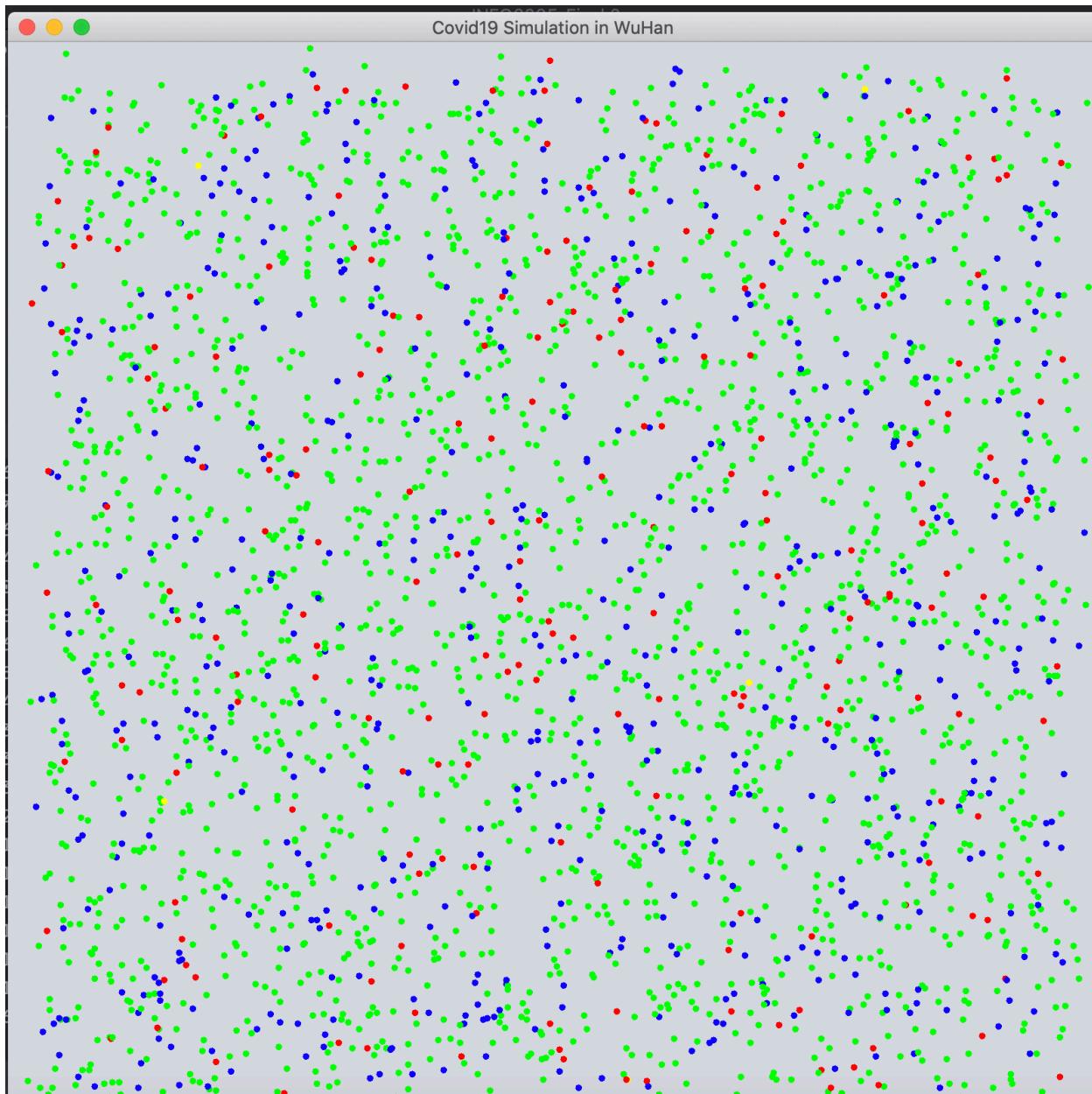
Pertussis Simulation Result



CityInfoJFrame ×

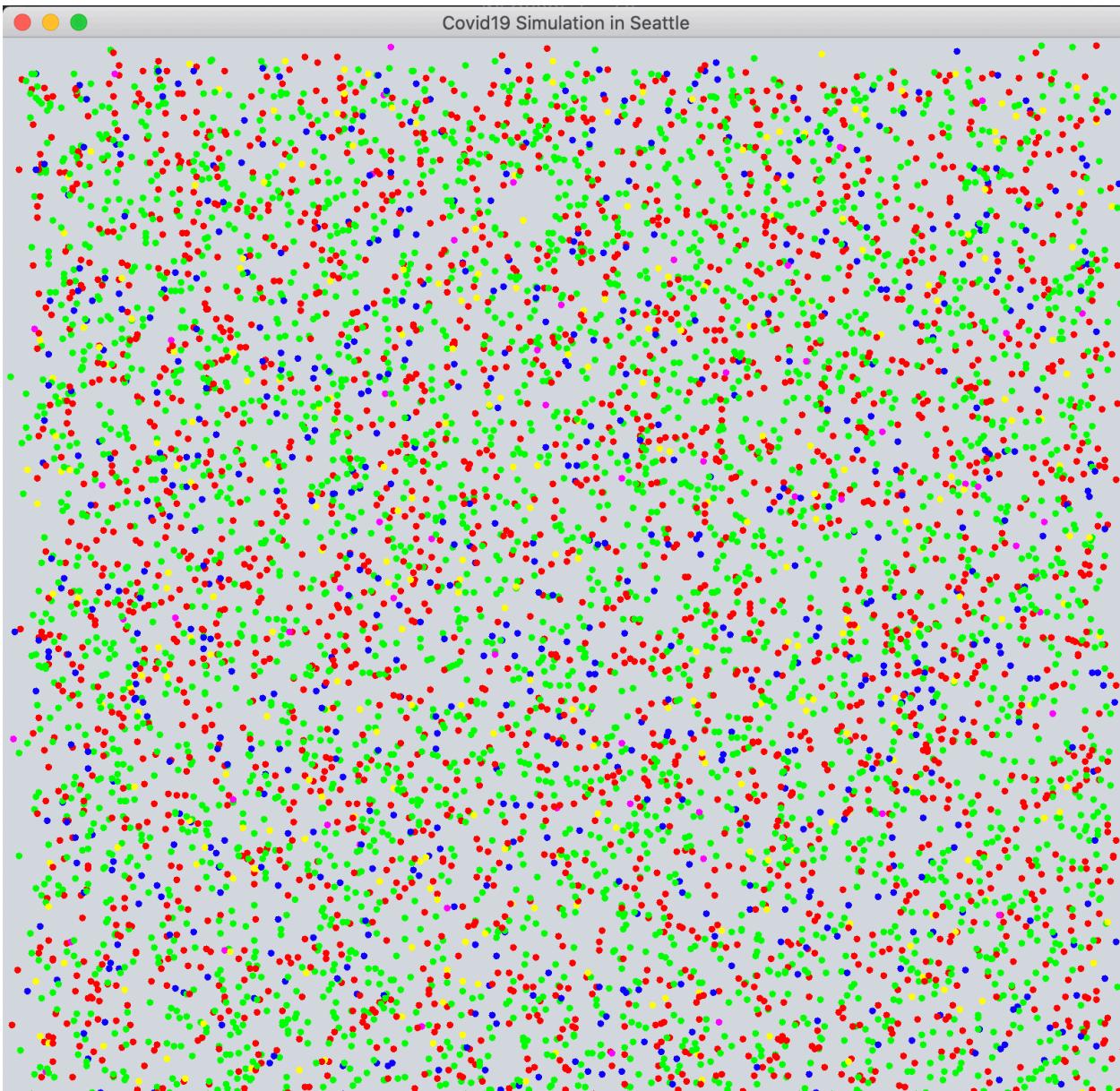
```
Recover: 0 Susceptible: 4900 Quarantined: 0 Exposed: 0 Infected: 100 Death: 0
Recover: 30 Susceptible: 3186 Quarantined: 28 Exposed: 1716 Infected: 42 Death: 0
Recover: 30 Susceptible: 2263 Quarantined: 28 Exposed: 2638 Infected: 42 Death: 0
Recover: 30 Susceptible: 1485 Quarantined: 28 Exposed: 3415 Infected: 42 Death: 0
Recover: 30 Susceptible: 863 Quarantined: 28 Exposed: 4038 Infected: 42 Death: 0
Recover: 30 Susceptible: 317 Quarantined: 28 Exposed: 4583 Infected: 42 Death: 0
Recover: 54 Susceptible: 4 Quarantined: 19 Exposed: 3948 Infected: 975 Death: 0
Recover: 54 Susceptible: 4 Quarantined: 19 Exposed: 2636 Infected: 2287 Death: 0
Recover: 54 Susceptible: 4 Quarantined: 19 Exposed: 1755 Infected: 3168 Death: 0
Recover: 54 Susceptible: 4 Quarantined: 19 Exposed: 1073 Infected: 3850 Death: 0
Recover: 54 Susceptible: 4 Quarantined: 19 Exposed: 510 Infected: 4414 Death: 0
Recover: 54 Susceptible: 2 Quarantined: 19 Exposed: 4 Infected: 4921 Death: 0
Recover: 1598 Susceptible: 2 Quarantined: 996 Exposed: 0 Infected: 2344 Death: 6
Recover: 2668 Susceptible: 2 Quarantined: 670 Exposed: 0 Infected: 1633 Death: 6
Recover: 3364 Susceptible: 2 Quarantined: 474 Exposed: 0 Infected: 1154 Death: 6
Recover: 3879 Susceptible: 2 Quarantined: 333 Exposed: 0 Infected: 779 Death: 7
Recover: 4236 Susceptible: 2 Quarantined: 228 Exposed: 0 Infected: 526 Death: 7
Recover: 4475 Susceptible: 1 Quarantined: 162 Exposed: 1 Infected: 353 Death: 8
Recover: 4638 Susceptible: 1 Quarantined: 107 Exposed: 1 Infected: 245 Death: 8
Recover: 4748 Susceptible: 1 Quarantined: 69 Exposed: 0 Infected: 174 Death: 8
Recover: 4833 Susceptible: 1 Quarantined: 45 Exposed: 0 Infected: 113 Death: 8
Recover: 4887 Susceptible: 1 Quarantined: 31 Exposed: 0 Infected: 73 Death: 8
Recover: 4915 Susceptible: 1 Quarantined: 23 Exposed: 0 Infected: 53 Death: 8
Recover: 4936 Susceptible: 1 Quarantined: 17 Exposed: 0 Infected: 38 Death: 8
Recover: 4961 Susceptible: 1 Quarantined: 9 Exposed: 0 Infected: 21 Death: 8
Recover: 4969 Susceptible: 1 Quarantined: 8 Exposed: 0 Infected: 14 Death: 8
Recover: 4974 Susceptible: 1 Quarantined: 6 Exposed: 0 Infected: 11 Death: 8
Recover: 4979 Susceptible: 1 Quarantined: 4 Exposed: 0 Infected: 8 Death: 8
Recover: 4982 Susceptible: 1 Quarantined: 2 Exposed: 0 Infected: 7 Death: 8
Recover: 4984 Susceptible: 1 Quarantined: 1 Exposed: 0 Infected: 6 Death: 8
Recover: 4987 Susceptible: 0 Quarantined: 1 Exposed: 1 Infected: 3 Death: 8
Recover: 4987 Susceptible: 0 Quarantined: 1 Exposed: 0 Infected: 4 Death: 8
```

Covid-19 Simulation In WuHan



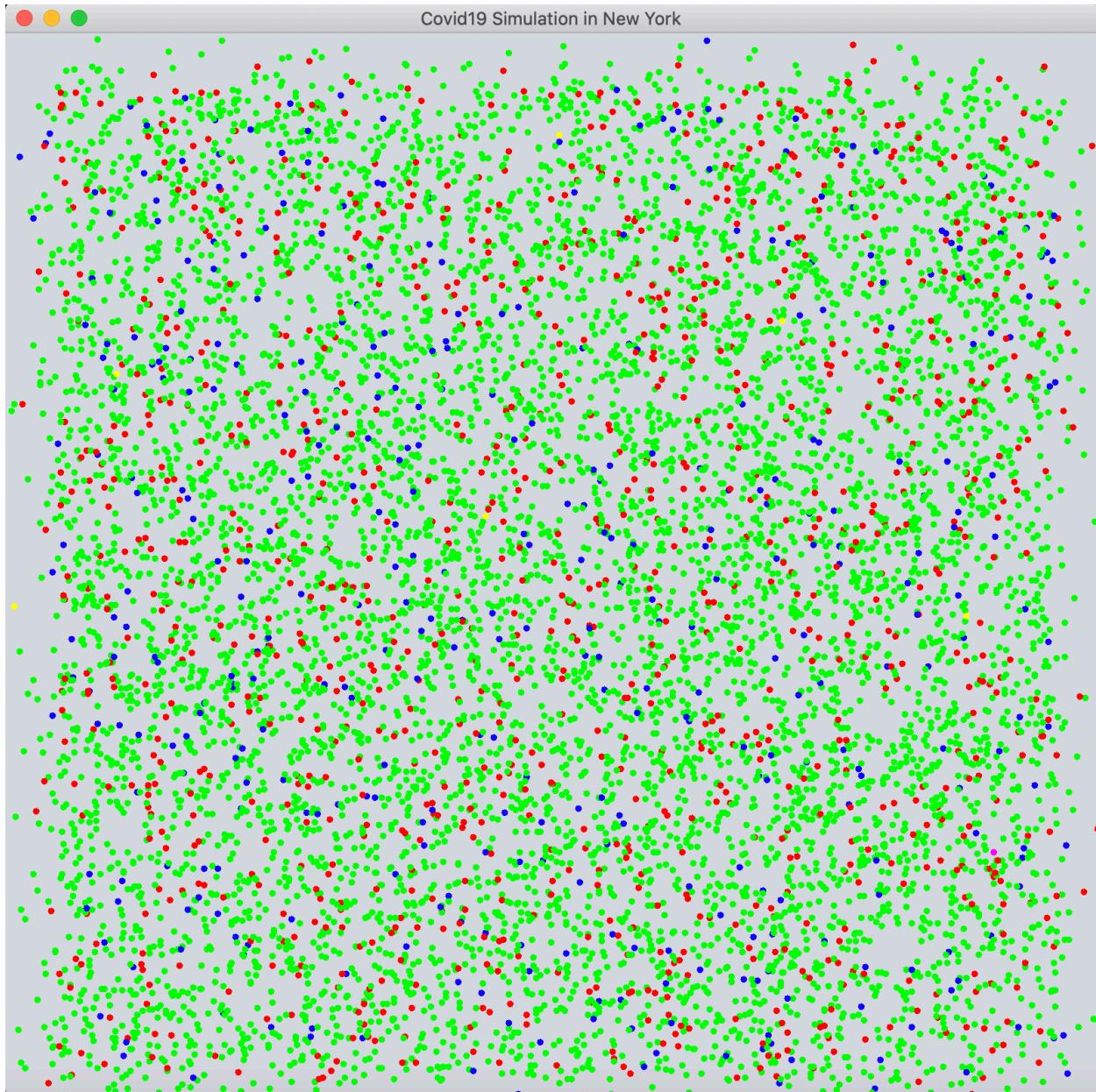
```
Recover: 0 Susceptible: 2900 Quarantined: 0 Exposed: 0 Infected: 100 Death: 0
Recover: 5 Susceptible: 2204 Quarantined: 70 Exposed: 699 Infected: 25 Death: 0
Recover: 7 Susceptible: 1666 Quarantined: 69 Exposed: 577 Infected: 681 Death: 0
Recover: 57 Susceptible: 1207 Quarantined: 554 Exposed: 371 Infected: 798 Death: 10
Recover: 130 Susceptible: 936 Quarantined: 877 Exposed: 279 Infected: 760 Death: 17
Recover: 211 Susceptible: 715 Quarantined: 1074 Exposed: 226 Infected: 751 Death: 23
Recover: 291 Susceptible: 551 Quarantined: 1230 Exposed: 169 Infected: 727 Death: 32
Recover: 389 Susceptible: 448 Quarantined: 1303 Exposed: 106 Infected: 716 Death: 38
Recover: 486 Susceptible: 345 Quarantined: 1362 Exposed: 104 Infected: 656 Death: 47
Recover: 581 Susceptible: 267 Quarantined: 1374 Exposed: 79 Infected: 650 Death: 49
Recover: 665 Susceptible: 199 Quarantined: 1386 Exposed: 70 Infected: 621 Death: 59
Recover: 760 Susceptible: 169 Quarantined: 1368 Exposed: 30 Infected: 603 Death: 70
Recover: 866 Susceptible: 141 Quarantined: 1337 Exposed: 28 Infected: 552 Death: 76
Recover: 961 Susceptible: 103 Quarantined: 1287 Exposed: 39 Infected: 527 Death: 83
Recover: 1063 Susceptible: 82 Quarantined: 1224 Exposed: 22 Infected: 520 Death: 89
Recover: 1156 Susceptible: 69 Quarantined: 1184 Exposed: 13 Infected: 488 Death: 90
Recover: 1243 Susceptible: 53 Quarantined: 1140 Exposed: 16 Infected: 454 Death: 94
Recover: 1314 Susceptible: 44 Quarantined: 1100 Exposed: 9 Infected: 436 Death: 97
Recover: 1400 Susceptible: 39 Quarantined: 1045 Exposed: 5 Infected: 406 Death: 105
Recover: 1461 Susceptible: 35 Quarantined: 1011 Exposed: 4 Infected: 378 Death: 111
Recover: 1534 Susceptible: 31 Quarantined: 956 Exposed: 4 Infected: 361 Death: 114
Recover: 1596 Susceptible: 23 Quarantined: 907 Exposed: 8 Infected: 347 Death: 119
Recover: 1673 Susceptible: 18 Quarantined: 858 Exposed: 5 Infected: 326 Death: 120
Recover: 1733 Susceptible: 15 Quarantined: 822 Exposed: 3 Infected: 305 Death: 122
Recover: 1800 Susceptible: 15 Quarantined: 777 Exposed: 0 Infected: 282 Death: 126
Recover: 1863 Susceptible: 13 Quarantined: 734 Exposed: 2 Infected: 261 Death: 127
Recover: 1905 Susceptible: 12 Quarantined: 707 Exposed: 1 Infected: 245 Death: 130
Recover: 1953 Susceptible: 11 Quarantined: 672 Exposed: 1 Infected: 231 Death: 132
Recover: 2002 Susceptible: 6 Quarantined: 636 Exposed: 5 Infected: 218 Death: 133
Recover: 2044 Susceptible: 6 Quarantined: 604 Exposed: 0 Infected: 212 Death: 133
Recover: 2092 Susceptible: 5 Quarantined: 573 Exposed: 1 Infected: 193 Death: 136
```

Covid 19 in Seattle



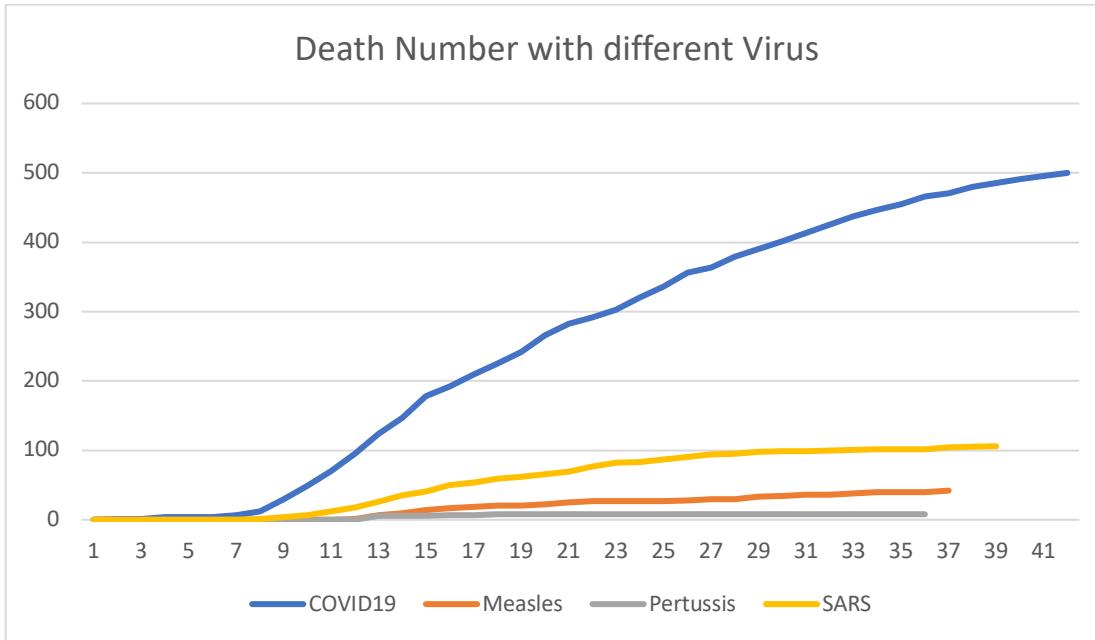
Recover: 0 Susceptible:	7900	Quarantined:	0	Exposed:	0	Infected:	100	Death:	0
Recover: 7 Susceptible:	7651	Quarantined:	18	Exposed:	249	Infected:	74	Death:	1
Recover: 7 Susceptible:	7339	Quarantined:	18	Exposed:	562	Infected:	74	Death:	1
Recover: 7 Susceptible:	7017	Quarantined:	18	Exposed:	883	Infected:	74	Death:	1
Recover: 7 Susceptible:	6740	Quarantined:	18	Exposed:	1161	Infected:	74	Death:	1
Recover: 7 Susceptible:	6480	Quarantined:	18	Exposed:	1420	Infected:	74	Death:	1
Recover: 7 Susceptible:	6212	Quarantined:	18	Exposed:	1688	Infected:	74	Death:	1
Recover: 9 Susceptible:	6014	Quarantined:	17	Exposed:	1701	Infected:	257	Death:	2
Recover: 9 Susceptible:	5830	Quarantined:	17	Exposed:	1685	Infected:	457	Death:	2
Recover: 9 Susceptible:	5614	Quarantined:	17	Exposed:	1661	Infected:	697	Death:	2
Recover: 9 Susceptible:	5382	Quarantined:	17	Exposed:	1674	Infected:	916	Death:	2
Recover: 9 Susceptible:	5184	Quarantined:	17	Exposed:	1677	Infected:	1111	Death:	2
Recover: 9 Susceptible:	4985	Quarantined:	17	Exposed:	1682	Infected:	1305	Death:	2
Recover: 28 Susceptible:	4815	Quarantined:	77	Exposed:	1592	Infected:	1483	Death:	5
Recover: 44 Susceptible:	4637	Quarantined:	125	Exposed:	1538	Infected:	1647	Death:	9
Recover: 54 Susceptible:	4436	Quarantined:	173	Exposed:	1493	Infected:	1832	Death:	12
Recover: 66 Susceptible:	4278	Quarantined:	221	Exposed:	1409	Infected:	2009	Death:	17
Recover: 85 Susceptible:	4113	Quarantined:	262	Exposed:	1353	Infected:	2170	Death:	18
Recover: 125 Susceptible:	3927	Quarantined:	315	Exposed:	1271	Infected:	2337	Death:	25
Recover: 161 Susceptible:	3761	Quarantined:	379	Exposed:	1187	Infected:	2484	Death:	28
Recover: 183 Susceptible:	3622	Quarantined:	423	Exposed:	1100	Infected:	2641	Death:	31
Recover: 217 Susceptible:	3480	Quarantined:	462	Exposed:	1033	Infected:	2773	Death:	35
Recover: 271 Susceptible:	3325	Quarantined:	523	Exposed:	940	Infected:	2897	Death:	45
Recover: 318 Susceptible:	3162	Quarantined:	563	Exposed:	876	Infected:	3028	Death:	54
Recover: 361 Susceptible:	3023	Quarantined:	606	Exposed:	836	Infected:	3116	Death:	59
Recover: 434 Susceptible:	2868	Quarantined:	646	Exposed:	777	Infected:	3200	Death:	75
Recover: 485 Susceptible:	2717	Quarantined:	685	Exposed:	748	Infected:	3283	Death:	83
Recover: 543 Susceptible:	2580	Quarantined:	711	Exposed:	722	Infected:	3349	Death:	96
Recover: 615 Susceptible:	2451	Quarantined:	735	Exposed:	669	Infected:	3426	Death:	104
Recover: 687 Susceptible:	2308	Quarantined:	762	Exposed:	623	Infected:	3501	Death:	119
Recover: 750 Susceptible:	2181	Quarantined:	782	Exposed:	589	Infected:	3569	Death:	129

Covid 19 in New York

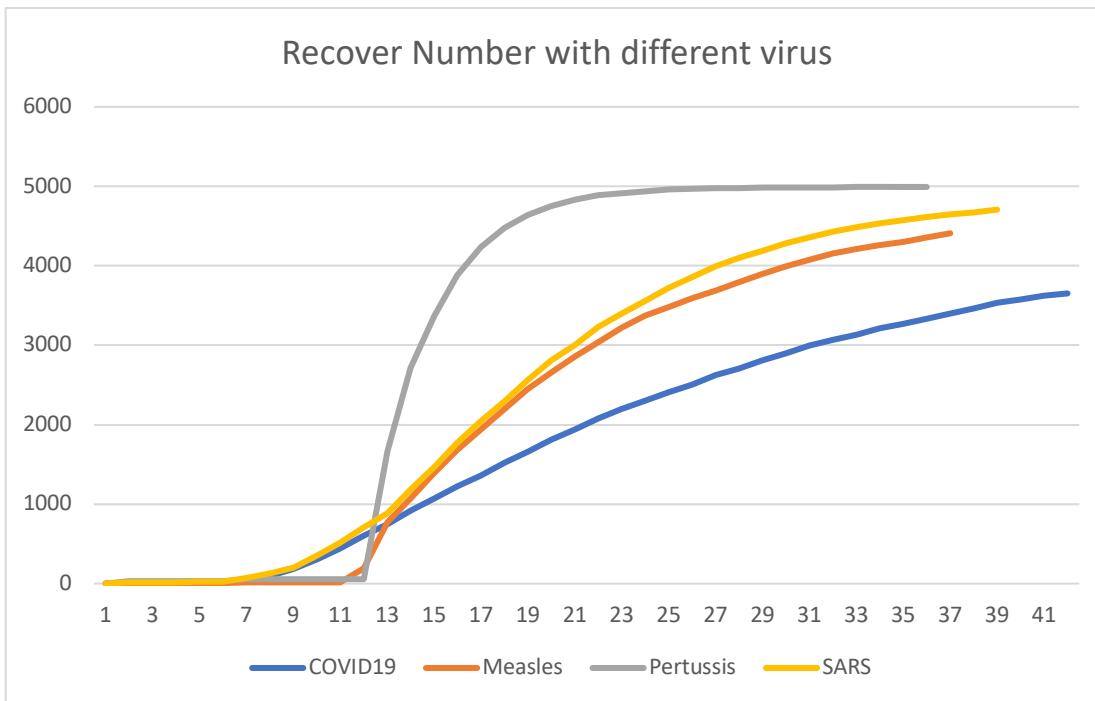


CityInfoFrame						
Recover:	2840	Susceptible:	772	Quarantined:	1184	Exposed: 162 Infected: 4574 Death: 468
Recover:	3103	Susceptible:	676	Quarantined:	1142	Exposed: 145 Infected: 4422 Death: 513
Recover:	3384	Susceptible:	575	Quarantined:	1124	Exposed: 117 Infected: 4241 Death: 559
Recover:	3700	Susceptible:	476	Quarantined:	1090	Exposed: 108 Infected: 4025 Death: 601
Recover:	4040	Susceptible:	380	Quarantined:	1028	Exposed: 78 Infected: 3801 Death: 672
Recover:	4338	Susceptible:	313	Quarantined:	987	Exposed: 65 Infected: 3575 Death: 721
Recover:	4574	Susceptible:	264	Quarantined:	945	Exposed: 59 Infected: 3394 Death: 759
Recover:	4781	Susceptible:	218	Quarantined:	911	Exposed: 53 Infected: 3245 Death: 792
Recover:	4975	Susceptible:	180	Quarantined:	874	Exposed: 47 Infected: 3102 Death: 821
Recover:	5183	Susceptible:	155	Quarantined:	832	Exposed: 32 Infected: 2936 Death: 861
Recover:	5363	Susceptible:	136	Quarantined:	798	Exposed: 23 Infected: 2785 Death: 894
Recover:	5522	Susceptible:	117	Quarantined:	770	Exposed: 22 Infected: 2644 Death: 922
Recover:	5684	Susceptible:	106	Quarantined:	744	Exposed: 14 Infected: 2500 Death: 952
Recover:	5827	Susceptible:	84	Quarantined:	715	Exposed: 23 Infected: 2370 Death: 980
Recover:	5987	Susceptible:	68	Quarantined:	683	Exposed: 19 Infected: 2233 Death: 1010
Recover:	6123	Susceptible:	57	Quarantined:	659	Exposed: 13 Infected: 2122 Death: 1026
Recover:	6255	Susceptible:	50	Quarantined:	636	Exposed: 10 Infected: 1994 Death: 1054
Recover:	6397	Susceptible:	45	Quarantined:	612	Exposed: 9 Infected: 1857 Death: 1080
Recover:	6516	Susceptible:	35	Quarantined:	582	Exposed: 12 Infected: 1751 Death: 1103
Recover:	6641	Susceptible:	33	Quarantined:	552	Exposed: 3 Infected: 1648 Death: 1121
Recover:	6754	Susceptible:	24	Quarantined:	527	Exposed: 9 Infected: 1544 Death: 1142
Recover:	6847	Susceptible:	19	Quarantined:	504	Exposed: 6 Infected: 1468 Death: 1155
Recover:	6944	Susceptible:	18	Quarantined:	481	Exposed: 1 Infected: 1385 Death: 1170
Recover:	7032	Susceptible:	15	Quarantined:	459	Exposed: 3 Infected: 1303 Death: 1188
Recover:	7108	Susceptible:	11	Quarantined:	442	Exposed: 4 Infected: 1226 Death: 1209
Recover:	7184	Susceptible:	7	Quarantined:	426	Exposed: 4 Infected: 1155 Death: 1223
Recover:	7255	Susceptible:	6	Quarantined:	408	Exposed: 1 Infected: 1093 Death: 1237
Recover:	7323	Susceptible:	6	Quarantined:	393	Exposed: 0 Infected: 1029 Death: 1249
Recover:	7389	Susceptible:	5	Quarantined:	365	Exposed: 1 Infected: 980 Death: 1260
Recover:	7465	Susceptible:	4	Quarantined:	343	Exposed: 1 Infected: 920 Death: 1267
Recover:	7528	Susceptible:	3	Quarantined:	332	Exposed: 1 Infected: 860 Death: 1276
Recover:	7594	Susceptible:	3	Quarantined:	313	Exposed: 0 Infected: 807 Death: 1283

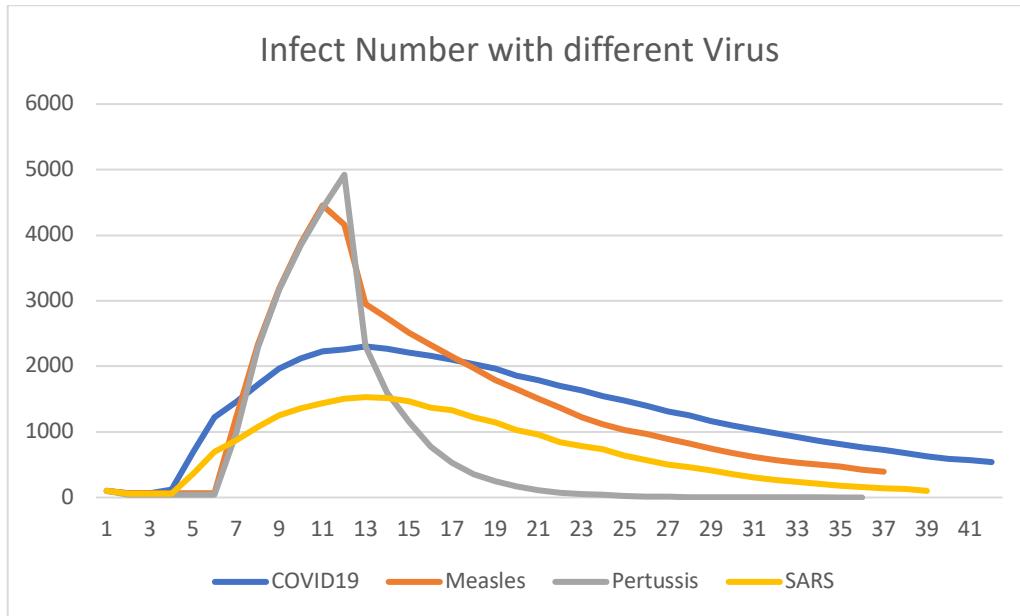
3.5 Comparison in various viruses



As we can see in the chart above, simulation on 4 different respiratory diseases comes out a significant difference on fatality rate and recovery rates. Covid-19 is the most damageable virus in the group.

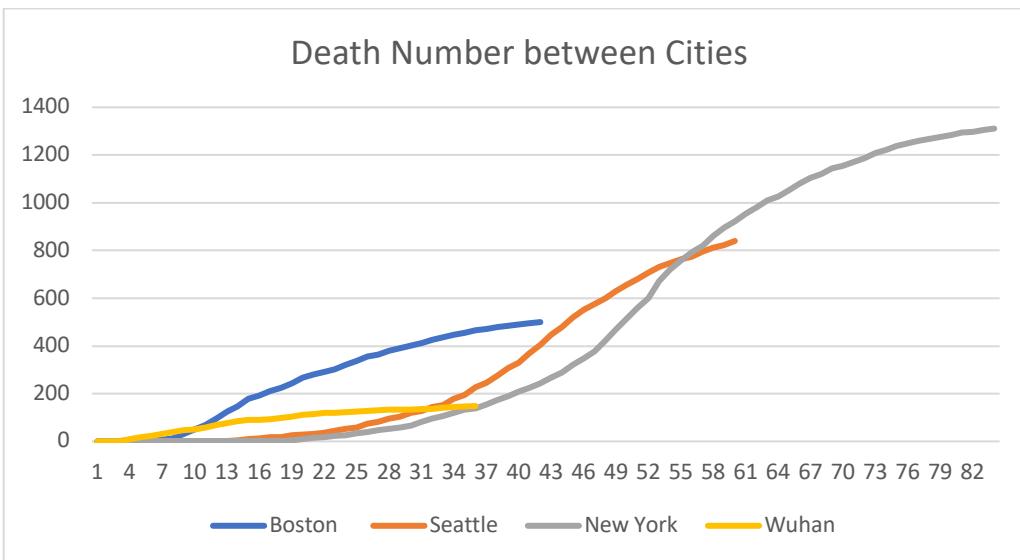


According to CDC's data, each virus infects different group of people. The diagram down below shows relationship between them.

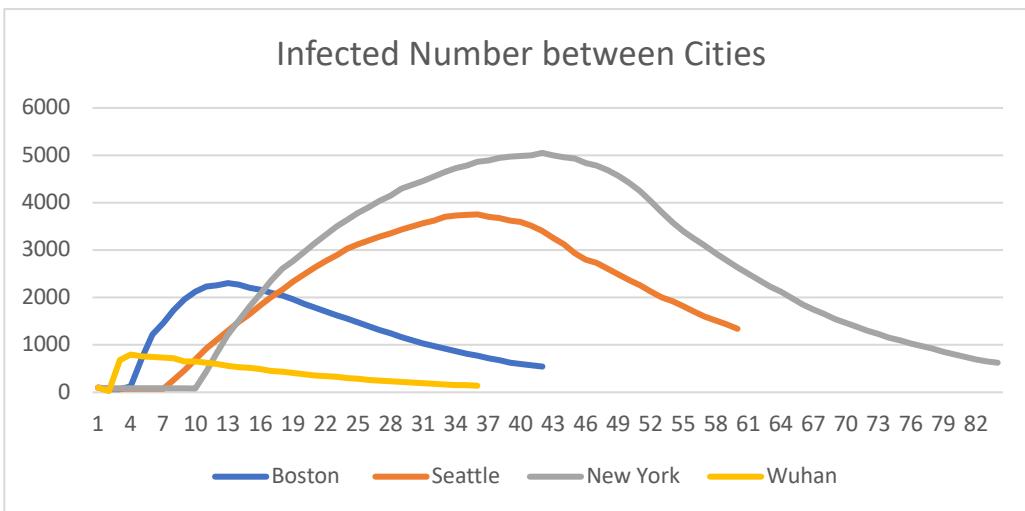
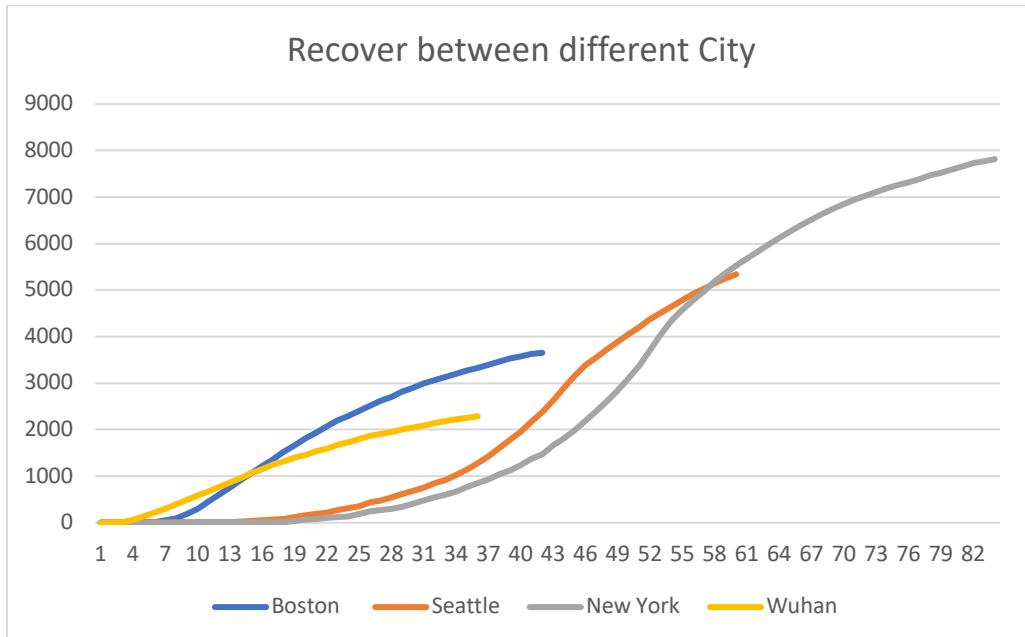


As social environment various in different cities, the amount of people who take masks and level of apply social distancing various as well. The transmission pattern of diseases shows significant difference. The diagram above is made based on data from local Center of Disease Controlling. Research shows that city has more citizen with high educated level usually ends up with less fatality rate.

Although it various on measures local government applied, the sense of taking masks and keep social distancing goes on the top properties that affect the infectious rate and fatality rate.



It could also affect recovery rate in different cities. The comparison of recovery rate shows down below.



4. Test Results and Coverage

The screenshot shows the JUnit test results for the package 'info6205'. All 17 tests have passed, indicated by green checkmarks. The total execution time is 124 ms.

Test	Time
CityDictionaryTest	2 ms
VirusTest	0 ms
PersonDictionaryTest	6 ms
PersonTest	116 ms
measlesBostonStateTest	17 ms
covidBostonStateTest	10 ms
covidWuhanStateTest	43 ms
distanceTest0	0 ms
stateTest2	0 ms
stateTest3	0 ms
moveTest	1 ms
covidNewYorkStateTest	24 ms
covidSeattleStateTest	10 ms
pertussisBostonStateTest	4 ms
sarsBostonStateTest	7 ms

The screenshot shows the code coverage report for the package 'info6205'. The report indicates 100% classes and 84% lines covered in 'all classes in scope'.

Element	Class, %	Method, %	Line, %
com.info6205.City	100% (6/6)	75% (18/24)	90% (74/82)
com.info6205.entity	100% (2/2)	100% (16/16)	68% (59/86)
com.info6205.util	100% (1/1)	100% (1/1)	94% (34/36)
com.info6205.Virus	100% (6/6)	85% (17/20)	92% (60/65)

All cases passed and coverage in line of the code are all over 60%.

5. Conclusion

According to the output results and comparation with the uninterpreted area, area with inference has better performance on controlling the transmission of disease.

Areas with people who take masks are getting lower infectious rate on every process of transmission. The property to represent the effect of taking masks is Mask Index (M_{mas}). It measures the average level of how masks cut off the way of transmitting disease in specific area.

In areas with social distancing has lower infectious rate compare to the uninterpreted area as adding distance between persons would further reducing the Social Distancing Index. As we can see in simulation results, number of exposed persons reduces significantly.

Simulation results also show that quarantine applies a positive effect on reducing the transmitting rate. By quarantining, it is an efficient way cutting of the transmitting path.

By comparison, taking masks and quarantining are the two most efficient way of reducing infectious rate for respiratory diseases. It blocks the infected group and other roles out to be avoided of getting respiratory contact.

6. Reference

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