# Research of Ebola-Propagation Model

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**Keywords:** Ebola; propagation; cellular automaton.

**Abstract.** To face with the outbreak of Ebola, we construct an accurate models to study the spread-behavior of the virus. We develop our precise model with the method of cellular automaton. Taking three factors into account, we can establish differential equation and expect the change of the proportion of the infective and the susceptible respectively. Then we add more influencing factors such as patient isolation to simulate a relatively-true process of virus-spread. Specially, with Monte Carlo method we change the related parameters to simulate two processes at different stages of infection. The results demonstrate that our refined model has a high confidence.

## 1. Introduction

Ebola, the deadly hemorrhagic fever was first discovered in 1976, and it has been haunting the public for twenty years. According to the World Health Organization, although the world medical association has announced that its new medication could stop Ebola and cure patients whose disease is not advanced, a relatively-reliable mathematical model on disease-spread may help to understand the nature of virus-spread and shed light on a more effective restriction on the spreading.

## 2. Spreading Model

### 2.1. Assumptions

Ebola spreads in a certain area.

There is no large-scale migration and immigration while the disease is spreading.

The patient who has been cured won't be infected anymore.

The total number of people in the virus-spread area is constant.

The virus cannot be spread by corpses.

### 2.2. Model Developing

First, in our model, we define some symbols as follows.

$N$ : The total number in the inspecting area

$\eta$ : The proportion of dead people in patient every day

$\mu$ : The proportion of cured people in patient every day

$\lambda$ : The people infected by one person every day

$i_0$ : The proportion of patient in the initial time

$S_0$ : The proportion of susceptible people in the initial time

$s(t)$ : The proportion of the susceptible in total number

$i(t)$ : The proportion of the infective in total number

$r(t)$ : The proportion of dead or cured people in total number

According to the assumption, we suppose that every infective person can infect $\lambda s(t)$ susceptible people into patient every day. Then, because the total number of patient is $Ni(t)$, the daily-increasing number of patients is $\lambda Nis$. However, there are also certain amount of people dead or cured every day, we assume the number of these people is $\mu Ni + \eta Ni$.

Based on the discussion above, we construct our model as follows.

 

$$\begin{cases} N\dfrac{ds}{dt} = -\lambda Nis \\ N\dfrac{di}{dt} = \lambda Nis - \mu Ni - \eta Ni \\ N\dfrac{dr}{dt} = \mu Ni + \eta Ni \\ s + r + i = 1 \\ i(0) = \boldsymbol{i}_0 \\ s(0) = \boldsymbol{S}_0 \end{cases}$$

In order to understand how the Ebola spread in a real situation, we have to analyze the behavior of virus-spread in a relatively-realistic situation. One intuition for modeling the problem is to think of it as a stochastic process. Therefore, we use a cellular automaton to simulate the behavior of virus-spread, setting several laws. These laws are sequentially implemented in every time-step.

(1)Law 1 Incubation period of virus ( $IP$ )

After a person is infected, he won't fall ill right now. There is an incubation period of virus which is 5-10 days and during the period he is not able to infect any other.

$IP$ =5-10 days

(2)Law 2 Pathogenesis period of virus ( $PP$ )

After the incubation period, the onset of symptoms will appear. Yet the initial symptoms are familiar to that of flu, most infectors won't pay much attention to. We call this period "Pathogenesis period of virus ( $PP$ )".

(3)Law 3 Patient isolation

We assume that after the pathogenesis period of virus, the suspected will go to see a doctor. When an infector is diagnosed with Ebola, he will be isolated in order to cut off the virus-spread. Consequently, he will not be able to infect other people any more.

(4)Law 4 Infection

According to the laws defined above, it is obvious that infectors mainly infect other people during the pathogenesis period. We set the number of people infected by one person every day as $\delta$ which is 0-2 and the maximum number of people infected by one person as $MN$

$\delta$ =0-2

(5)Law 5 Death time

While some suspected patients are diagnosed and isolated, others lack of timely treatments and will die in 7-14 days after pathogenesis period. Additionally, we set the proportion of isolated people in total infected patients as $\alpha$ and the proportion of dead people in total infected patients as $\beta$

$DT$ =7-14 days

$\alpha$ =80%

$\beta$ =20%

Model Testing. We will use two cases below to prove the reliability of our model.

(i). The case of Monrovia

Based on the data from Literature [2], we can see that the number of Ebola cases in Monrovia appear a tendency of exponential growth.

We consider this situation occurs in the initial period of the outbreak and because of lack of effective respond, the disease will spread without restrictions. Therefore, we set

$PP$ =3-5 days

$MN$ =5

We run several simulations with cellular automaton. The two figures below show the real curve and the simulation curve.

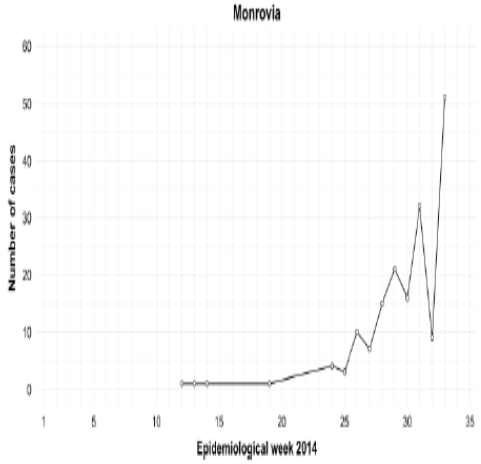


Figure1 The actual weekly-increasing number of cases in Monrovia

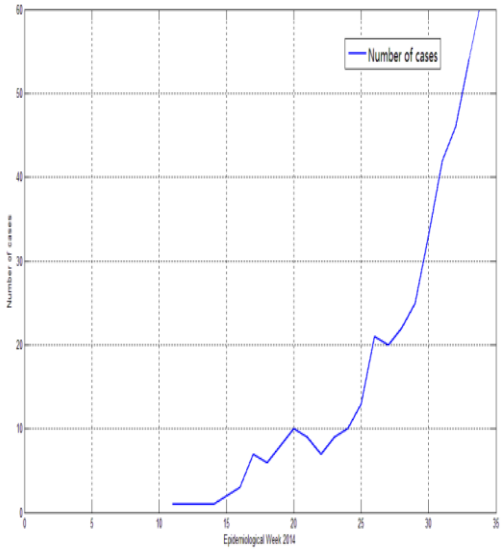


Figure2 The simulated weekly-increasing number of cases in Monrovia

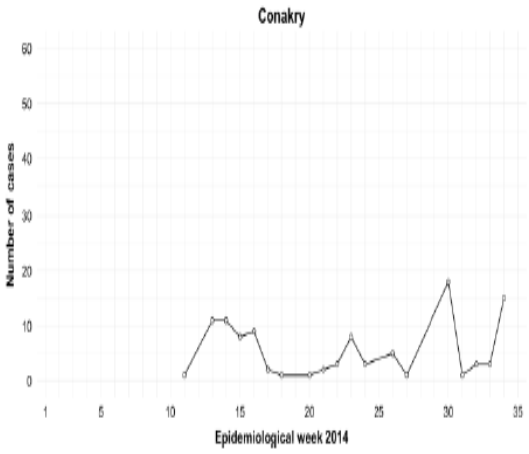


Figure 3 The actual weekly-increasing number of cases in Conakry

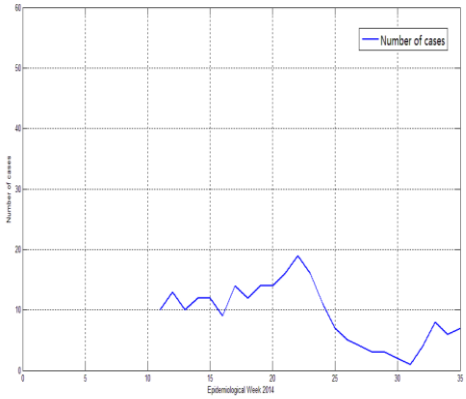


Figure 4 The simulated weekly-increasing number of cases in Conakry

(ii). The case of Conakry

We analyze the recent situation of Ebola-spread in Conakry, discovering that the disease has been controlled successfully. Hence, we set

$PP$ =0-3 days

$MN$ =2

To simulate the situation that the infectors are isolated strictly and infection rate is relatively low. The two figures below show the real curve and the simulation curve.

Result Analysis. Based on the discussion above, our refined model own an ideal imitative effect. On one hand, in terms of Figure2and Figure 3, we can see that the tendency of the simulation result is similar to realistic curve. At the beginning, although some people have been infected by the virus, they will not spread the disease at once because of the pathogenesis period of virus. But after this period, due to lack of immunity, the disease will spread rapidly, appearing an exponential growth. On the other hand, according to Figure 4 and Figure 5, the simulation result also correspond to the truth in a large degree. Since experts have taken action to deal with the disease and people also have paid much attention to protect themselves from the virus, less susceptible people will be infected and the total number of infectors fluctuate a certain value up and down.

## Reference

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