



Prevention and Control Countermeasures of COVID-19

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Abstract

The novel coronavirus has posed a threat to human life and safety. Accurately predicting the spread trend of the novel coronavirus and discovering prevention and control measures play an important role in the stable development of the whole human society. The infectious disease dynamics model can predict the development trend of COVID-19 and evaluate the impact of different prevention and control measures on the development of the epidemic, providing a scientific and reasonable theoretical basis for epidemic prevention and control decisions. Based on the traditional infectious disease model and the characteristics of the novel coronavirus epidemic, this paper improved and optimized the model to simulate and predict the development trend of the novel coronavirus epidemic, and analyzed the development status of the epidemic with different prevention and control measures. The traditional SIR model and SEIR model were used to predict and analyze the data of Hubei Province of China and Michigan of the United States in the early stage of the epidemic development. It was found that the prevention and control measures of China and the United States had an important impact on the development of the epidemic, and the SEIR model was further analyzed to improve the characteristics of the epidemic. The SEIR infectious disease dynamics model was constructed and the sensitivity of the improved SEIR model was tested. Through the study, it is found that the improved model is reliable in predicting the epidemic transmission trend in Hubei Province, and the prediction results of the model can provide strong support for the epidemic prevention and control strategies in the future.

Keywords: *COVID-19; epidemic situation; SEIR model*

1. Introduction

At the beginning of 2020, COVID-19 outbreak spread throughout the world. The spread of the epidemic caused not only a huge impact on human life, but unprecedented crisis faced by all walks of life. The dynamic model of infectious disease is a method that combines the actual case information with theoretical research. According to the characteristics of population growth, the occurrence, propagation and development of disease within the population, as well as the social factors related to it, a mathematical model can be established to reflect the dynamic characteristics of infectious disease. Through qualitative and quantitative analysis and numerical simulation of the model dynamics, the development process of the disease was analyzed, the epidemic law was explained, and the trend of change was predicted.

Dynamic model of infectious diseases is a modeling method for qualitative and quantitative research on the spread of infectious diseases. Daniel Bernoulli created the world's first pandemic bin model to study whether the vaccine will affect the infection or not[1].

W.O.Kermack and A.G. McKendrick established the first SIR warehouse model, which divided the population into three types: susceptible, infected and removed, and established the threshold theory to judge whether certain infectious disease is epidemic or not [2]. Since then, this model has become one of the most classic models in infectious disease models. The invent of computers pushed the improvement of infectious diseases model to a new peak. In 2006, Lekone et al. applied SIR model to the transmission of Ebola virus and estimated the parameters in the model using maximum likelihood estimation and Monte Carlo simulation [3]. In 2010, Foquah improved the SIR model. People have further understood the transmission mechanism of Ebola virus [4].

Since the beginning of the COVID-19 outbreak, a variety of scholars have used different methods to predict the COVID-19 epidemic. Joseph T Wu et al estimated the basic regeneration number with SEIR model, back-deduced the parameters, and concluded that 75815 people were infected in Wuhan on January 25, 2020 [5]. Wei Yongyue, et al. established the SEIR+CAQ model and used the optimization algorithm to get the conclusion that the national epidemic peak

would arrive on February 1, 2020, but the epidemic could be prevented and controlled [6]. Scholars such as Fan Ruguo and Wang Yibo analyzed the transmission characteristics of COVID-19 and predicted that the epidemic would reach an inflection point between February 20 and 25, 2020[7]. Harvard school of public health, scholars, based on SEIRS model under the assumption that countries can successfully control the outbreak to simulate the epidemic situation. The result shows that after controlling the outbreak, if the recovered are unable to get a permanent immunity, outbreak will come back[8]. In addition, in the later stage of the epidemic, scholars used SEIR model to evaluate the effectiveness of various prevention and control measures by comparing predicted data with actual data. Wang et al. used this method to estimate that the number of confirmed cases have decreased by 94.5% after the implementation of strict traffic control in Wuhan [9]. Wei Yongyue and other scholars used models to scientifically evaluate the effect of epidemic prevention and control and pointed out that the implementation of comprehensive prevention and control measures made the epidemic in Wuhan end 74 days earlier [10]. According to current research and analysis, the main method used to predict the COVID-19 epidemic is the infectious disease dynamics model. There are many factors affecting the development of epidemic. We need to study the most effective prevention and control measures to minimize the influence of the outbreak and facilitate people's work and life to go back on the right track as soon as possible.

This paper mainly uses the infectious disease dynamics model to predict and analyze the development of the novel coronavirus epidemic, so that people can have a more intuitive and comprehensive understanding of the various stages of infectious diseases spread, scientifically evaluate the effects of various treatment and control programs, and put forward effective prevention and control strategies through research.

2. Novel Coronavirus Transmission analysis based on infectious disease model

2.1. SIR model predictive analysis

SIR model divides the total population into three categories: susceptible population (S), infected population (I) and removed population (R). Assuming the total population is N, then $N=S(t)+I(t)+R(t)$. The analysis of the current COVID-19 by using SIR model can be divided into three stages:

- Establish SIR model: build SIR model by analyzing epidemic characteristics
- Analyze and determine model parameters: determine relevant parameters through statistical analysis of historical epidemic data or literature review;
- Simulation prediction analysis: Write programs with MATLAB, input relevant parameter information, and simulate and predict the TREND of COVID-19 epidemic according to the model.

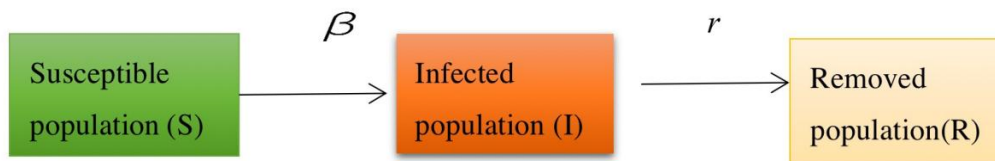


Fig.1 Structure of the SIR model

With the development of COVID-19, it is assumed that the probability of susceptible persons contacting patients and being infected is β ; the proportion of susceptible groups is S/N ; the number of people contacting patients per unit time is R , so the change rate of susceptible groups is

$$\frac{dS}{dt} = -r\beta I \frac{S}{N} \tag{1}$$

The increase number of infected people is provided by susceptible people, and the probability of the infected people converted into the removed state per unit time is γ , so the conversion rate of infected people is:

$$\frac{dI}{dt} = r\beta I \frac{S}{N} - \gamma I \tag{2}$$

The probability of the infected population converted to the removal state per unit time is γ , then the conversion rate of the removed people is:

$$\frac{dR}{dt} = \gamma I \tag{3}$$

In summary, we can get the SIR dynamic model of COVID-19:

$$\begin{cases} \frac{dS}{dt} = -r\beta I \frac{S}{N} \\ \frac{dI}{dt} = r\beta I \frac{S}{N} - \gamma I \\ \frac{dR}{dt} = \gamma I \end{cases} \tag{4}$$

After the above differential equations are differentiated, MATLAB is used to solve the difference equation, and its difference form is as below:

$$\begin{cases} S(i+1) = S(i) - r\beta I(i) \frac{S(i)}{N} \\ I(i+1) = I(i) + r\beta I(i) \frac{S(i)}{N} - \gamma I(i) \\ R(i+1) = R(i) + \gamma I(i) \end{cases} \quad (5)$$

2.2. SEIR model predictive analysis

To observe and analyze the actual cases, the incubation period of the novel coronavirus exists. According to the analysis and statistics of experts from

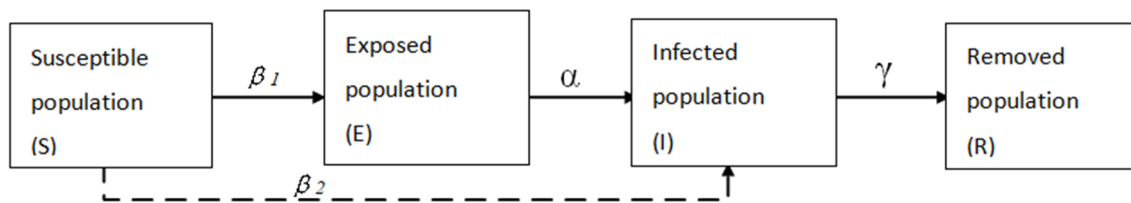


Fig.2 SEIR model structure diagram

With the transmission of novel coronavirus, it is assumed that the probability of susceptible people contacting exposed people and being infected per unit time is β_1 ; the probability of susceptible people contacting infected people and being infected per unit time is β_2 , the proportion of susceptible groups is S/N , and the number of contacts per unit time is denoted by R , so the change rate of susceptible population reduction is as follows:

$$\frac{dS}{dt} = -r[\beta_1 E + \beta_2 I] \frac{S}{N} \quad (6)$$

At the same time, the number of exposed people keeps increasing, and the probability of transforming into infection state per unit time is α , then the conversion rate of exposed people is:

$$\frac{dE}{dt} = r[\beta_1 E + \beta_2 I] \frac{S}{N} - \alpha E \quad (7)$$

The number of infected people is provided by the potential infected people, and the probability of transforming into the recovering state per unit time is γ , then the conversion rate of infected people is:

$$\frac{dI}{dt} = \alpha E - \gamma I \quad (8)$$

The probability of the infected population transforming to the recovering state in unit time is, and the change rate of the recovered population is

the National Health Commission, the incubation period of the Novel Coronavirus is about 7 days on average and up to 14 days with infectious characteristic. Therefore, we choose to introduce the incubation period on the basis of SIR prediction model. Susceptible people who contact with infected people do not immediately become patients, but become pathogen carriers, who have certain infectivity but will show symptoms of disease after a certain period of time, which is called exposed population (E). SEIR model divides the population into four categories: S, E, I and R, representing susceptible population, potential infected population, infected population and recovered population respectively, where $N=S(t)+E(t)+I(t)+R(t)$. The model structure diagram is as follows:

$$\frac{dR}{dt} = \gamma I \quad (9)$$

To sum up, we can get the SEIR dynamic model of the spread of COVID-19:

$$\begin{cases} \frac{dS}{dt} = -r[\beta_1 E + \beta_2 I] \frac{S}{N} \\ \frac{dE}{dt} = r[\beta_1 E + \beta_2 I] \frac{S}{N} - \alpha E \\ \frac{dI}{dt} = \alpha E - \gamma I \\ \frac{dR}{dt} = \gamma I \end{cases} \quad (10)$$

After the above differential equation is differentiated, MATLAB is used to solve the difference equation, and its difference form is as follows:

$$\begin{cases} S(i+1) = S(i) - r[\beta_1 E(i) + \beta_2 I(i)] \frac{S(i)}{N} \\ E(i+1) = E(i) + r[\beta_1 E(i) + \beta_2 I(i)] \frac{S(i)}{N} - \alpha E(i) \\ I(i+1) = I(i) + \alpha E(i) - \gamma I(i) \\ R(i+1) = R(i) + \gamma I(i) \end{cases} \quad (11)$$

2.3. Improved SEIR model predictive analysis

The traditional SEIR model does not consider the impact of the number of deaths, so this paper introduces new parameters to correct this problem. Based on the analysis of the actual situation and data, it can be seen that China did not take any prevention and control

measures at the initial stage of the epidemic. Since January 23, Wuhan city in Hubei Province has taken lockdown measures, and the China has taken measures to prevent and control the epidemic, such as isolation and medical assistance. At this time, the effective transmission coefficient between exposed people and infected people decreased, and the recovery rate of infected people improved. Meanwhile, hospitals began to quarantine some close contacts and potential infected people. Based on the above analysis, the quarantine ratio was added and a segmentation model is established to predict the development trend of COVID-19.

The segmentation model is established as follows:

Assuming that January 12 is the starting point of the epidemic and Wuhan city began to take lockdown measures on January 23. In other words, 11 days later, the mobility of people decreased, and the allocation of domestic medical resources was tilted towards Hubei province. The impact of government control on the development of the epidemic showed significantly.

The model of pre-control (free transmission period) infectious diseases is established as follows:

This process introduces the number of deaths on the basis of the traditional SEIR model, where the mortality rate is θ , so the pre-control model of Novel coronavirus transmission is:

$$\begin{cases} \frac{dS}{dt} = -r[\beta_1 E + \beta_2 I] \frac{S}{N} \\ \frac{dE}{dt} = r[\beta_1 E + \beta_2 I] \frac{S}{N} - \alpha E \\ \frac{dI}{dt} = \alpha E - (\gamma + \theta) I \\ \frac{dR}{dt} = \gamma I \\ \frac{dD}{dt} = \theta I \end{cases} \quad (12)$$

The differential of the above differential equation is as follows:

$$\begin{cases} S(i+1) = S(i) - r[\beta_1 E(i) + \beta_2 I(i)] S(i) / N \\ E(i+1) = E(i) + r[\beta_1 E(i) + \beta_2 I(i)] S(i) / N - \alpha E(i) \\ I(i+1) = I(i) + \alpha E(i) - (\gamma + \theta) I(i) \\ R(i+1) = R(i) + \gamma I(i) \\ D(i+1) = D(i) + \theta I(i) \end{cases} \quad (13)$$

The model of post-control infectious diseases is established as follows:

Through measures such as quarantine and travel restriction, the quarantine ratio is changed from 0 to Q, the number of daily contact between susceptible and exposed people is reduced, and the recovered rate was improved. At this point, the change rate of each population is analyzed by analogy with the pre-control model.

Assume that the probability of exposed people transforming into susceptible is μ , the quarantine ratio is Q, and the quarantine lifting rate is λ , at this time, the change rate of susceptible population is:

$$\frac{dS}{dt} = -(1+q)(r_1\beta_1 E + r_2\beta_2 I)S / N + \mu E + \lambda S_q \quad (14)$$

Among them, the exposed population keeps increasing and transforms into infected and susceptible people, where the negative conversion rate is expressed μ , so the change rate of exposed people is:

$$\frac{dE}{dt} = (r_1\beta_1 E + r_2\beta_2 I)S / N - (\mu + \alpha)E \quad (15)$$

The infected population is transformed from exposed population and quarantined close contacts, and may end up being recovered or dead. Assuming that the probability of exposed people and close contacts transforming into infected people is α and ω respectively, and the recovered rate and mortality rate are γ and θ respectively, then the rate of change of infected people is:

$$\frac{dI}{dt} = \alpha E + \omega S_q - (\gamma + \theta)I \quad (16)$$

The changing rate of close contacts in quarantine is:

$$\frac{dS_q}{dt} = q(r_1\beta_1 E + r_2\beta_2 I)S / N - (\alpha + \omega)S_q - \lambda S_q \quad (17)$$

The changing rate of the recovered people is:

$$\frac{dR}{dt} = \gamma I \quad (18)$$

The changing rate of deaths is:

$$\frac{dD}{dt} = \theta I \quad (19)$$

In conclusion, the post-control model of Novel Coronavirus transmission is as follows:

$$\begin{cases} \frac{dS}{dt} = -(1+q)(r_1\beta_1 E + r_2\beta_2 I)S / N + \mu E + \lambda S_q \\ \frac{dE}{dt} = (r_1\beta_1 E + r_2\beta_2 I)S / N - (\mu + \alpha)E \\ \frac{dI}{dt} = \alpha E + \omega S_q - (\gamma + \theta)I \\ \frac{dS_q}{dt} = q(r_1\beta_1 E + r_2\beta_2 I)S / N - (\alpha + \omega)S_q - \lambda S_q \\ \frac{dR}{dt} = \gamma I \\ \frac{dD}{dt} = \theta I \end{cases} \quad (20)$$

After the above differential equation is differentiated, MATLAB is used to solve the difference equation, and its difference form is as follows:

$$\begin{cases}
 S(i+1) = S(i) - (1+q)(r_1\beta_1E(i) + r_2\beta_2I(i))S(i) / N + \mu E(i) + \lambda S_q(i) \\
 E(i+1) = E(i) + (r_1\beta_1E(i) + r_2\beta_2I(i))S(i) / N - (\mu + \alpha)E(i) \\
 I(i+1) = I(i) + \alpha E(i) + \omega S_q(i) - (\gamma + \theta)I(i) \\
 S_q(i+1) = S_q(i) + q(r_1\beta_1E(i) + r_2\beta_2I(i))S(i) / N - (\alpha + \omega)S_q(i) - \lambda S_q(i) \\
 R(i+1) = R(i) + \gamma I(i) \\
 D(i+1) = D(i) + \theta I(i)
 \end{cases}
 \quad (21)$$

3. Analysis and forecast of COVID-19 in China

3.1. Data Acquisition

3.1.1. Index selection

This paper mainly selects the total number of confirmed infected COVID-19 cases, recovered COVID-19 cases and deaths in 2020 as the research objects. In the simulation prediction based on the infectious disease model, the number of confirmed infected cases and removed cases (cure and death) are mainly predicted.

3.1.2. Data Source (Wuhan)

The COVID-19 data used in this paper is compiled from the public data of the National Health Commission, provincial and urban health commissions, provincial and urban governments, and official channels of Hong Kong, Macao and Taiwan. The data are published on baidu APP "Real-time Big Data Report on the Epidemic" with authority and validity. We also supplement the missing data with resources in the local construction commission official website.

3.2. Analysis of SIR model prediction results

The SIR dynamic model with the transmission characteristics of COVID-19 is established, and the MATLAB platform is used for simulation to get the dynamic results of susceptible people, infected people and removed people over time in the transmission of Novel Coronavirus.

The peak number of infected people predicted by the above SIR model was 17,870,000, while the actual peak number of infected persons was 50,633. The predicted peak value is much higher than the actual data, and the simulation experiment had a large error. The analysis shows that the SIR model does not take into account the infectivity of novel Coronavirus incubation period and the influence of human intervention factors, thus leading to a large deviation between the predicted results and the actual results.

3.3. Analysis of SEIR model prediction results

The SEIR dynamic model with the transmission characteristics of COVID-19 is established, and the MATLAB platform is used for simulation to get the dynamic results of susceptible people, exposed people, infected people and removed people over time in the transmission of Novel Coronavirus.

We get the conclusion that in the process of transmission, whether it be exposed people or infected people, the trend is slowly increasing at the beginning of the outbreak epidemic and show rapid growth state in February 3, 2020 - February 10. Exposed people on February 15 or so will reach a peak value, and infected people peaked around February 17. After the peak, the number of exposed and infected people began to decrease gradually until they were both zero.

Compare the actual data with the forecast data, the prediction result of the COVID-19 epidemic by using SEIR model is not ideal. The predicted number of infected people and removed people (dying and cured) are both much higher than the actual data. It shows that the actual number of infected people peaked in February 18. Deviation is one day only, and the result of SEIR model prediction is similar to the actual change trend. Therefore, the traditional SEIR model has a high reference value in predicting the arrival of the turning point of COVID-19 and the overall development trend, but the model needs to be improved for more accurate analysis results.

3.4. Analysis of prediction results of improved SEIR model

3.4.1. Index selection

This paper mainly selects the total number of confirmed infected COVID-19 cases, cured COVID-19 cases and deaths in 2020 as the research objects. In the simulation prediction based on the infectious disease model, the number of confirmed infected cases and the number of removed cases (cure and death) are mainly predicted and compared with the actual analysis.

In the segmentation model, after government control, the number of contacts between the exposed population and the quarantined population is basically fixed. According to literature review, $R_1 = 1.8$, $R_2 = 0.2$, and the number of contacts between the exposed population and the infected population in the pre-control model is basically the same, $r = 13$. MATLAB platform is used for simulation to obtain improved model prediction results, as shown in Fig.3:

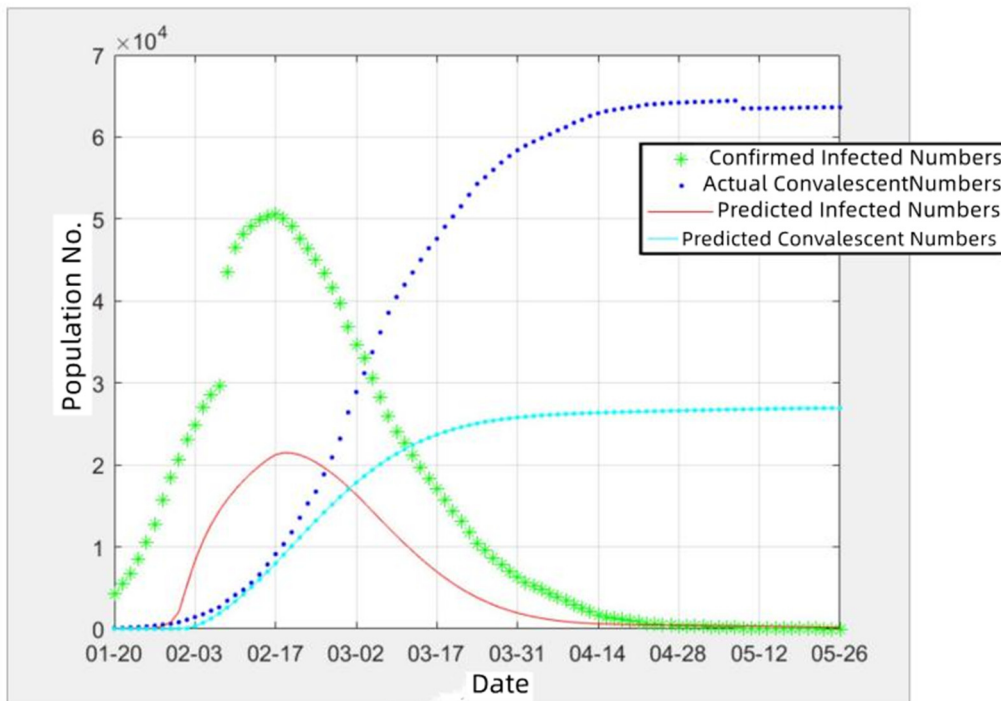


Fig.3 Prediction results of the improved SEIR model

Then we adjust the number of contacts r in the pre-control model, and the adjustment result is shown in Fig.4:

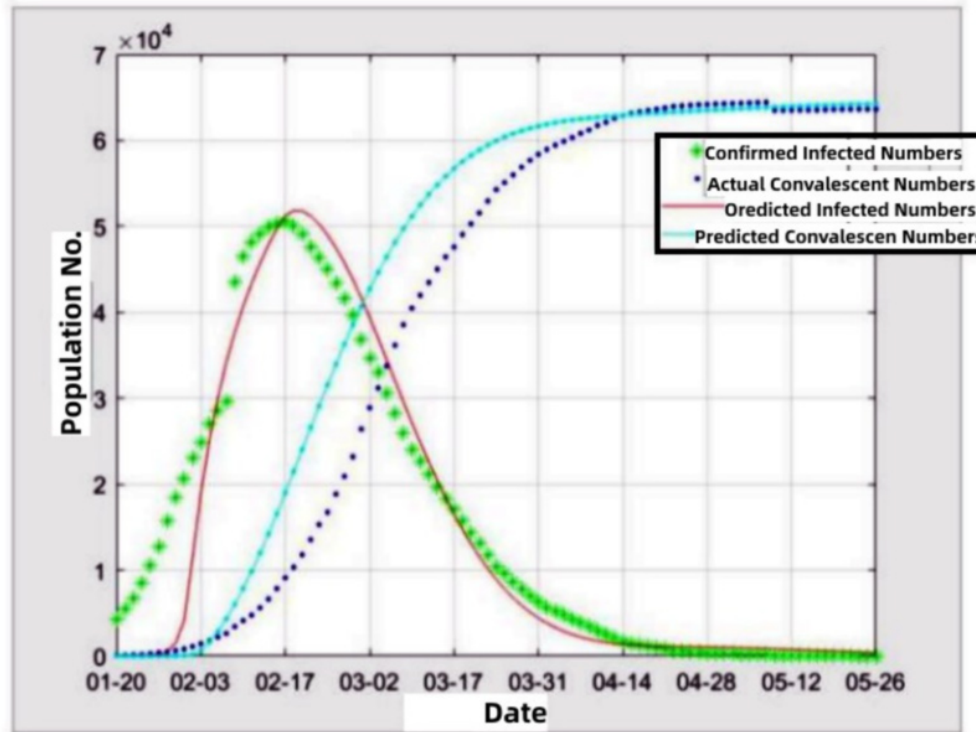


Fig.4 Prediction results when $R = 16$

According to the comparison, when $R = 16$, the prediction effect of COVID-19 is the best. Therefore, $R = 16$ is selected as the parameter of the pre-control model. Based on the above analysis, the evolution

results of the exposed, infected and removed people in the transmission of Novel coronavirus with time can be obtained, as shown in Fig.5:

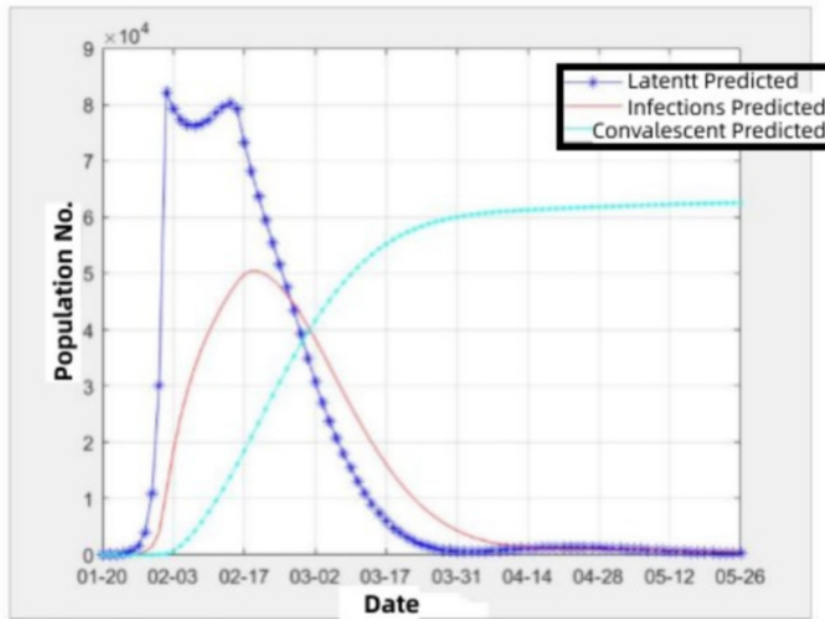


Fig.5 Prediction results of evolution of each population by improved SEIR model

The Fig.5 shows that in the epidemic, exposed population (E) and the number of infected people (type I) at the beginning of the epidemic tend to rise sharply. Around February 17, the number of exposed and infected people began to decline, the number of recovered people rose obviously after that, illustrating

the prevention and control of epidemic is overall effective, the spread rate of the virus dropped, and the outbreak was brought under control.

The actual number of infected and recovered people in Hubei province is compared with the predicted results of the model, as shown in Fig.6:

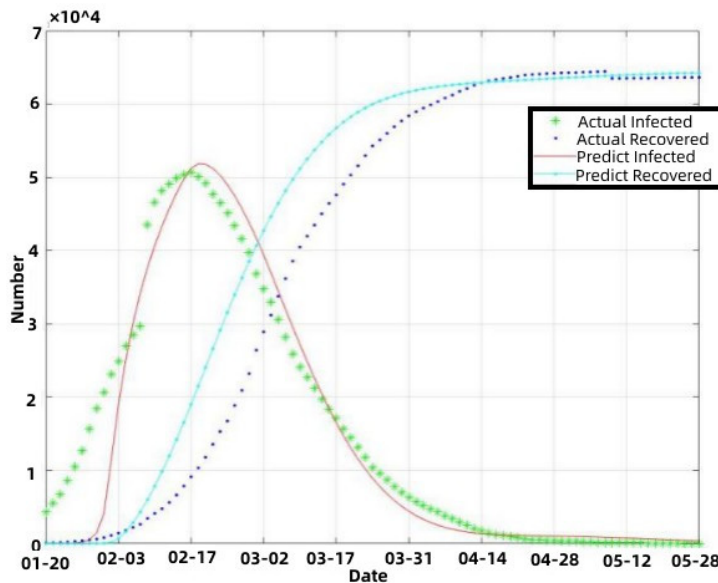


Fig.6 Comparison between predicted data and actual data of improved SEIR model

Fig.6 shows that the predicted data of the model is basically consistent with the actual data. In 2020, the peak of the actual number of patients in Hubei was 50,633, and the peak of the number of infected people predicted by the segmented model was 50,441, with a difference of only 0.38%. The model predicted the peak on February 20, and the actual peak on February 18, with a difference of only two days. Therefore, the segmentation model obtained after the improvement of

the traditional SEIR model in this paper is more accurate in predicting the development of COVID-19 epidemic in Hubei province, indicating that the parameters in the improved model and the model construction form are correct and reliable.

3.4.2. Sensitivity analysis

According to the improved model, countries usually

take quarantine measures to control the epidemic, then we consider the influence of control time and isolation intensity on the prediction results of the model.

① Control the influence of time on the model

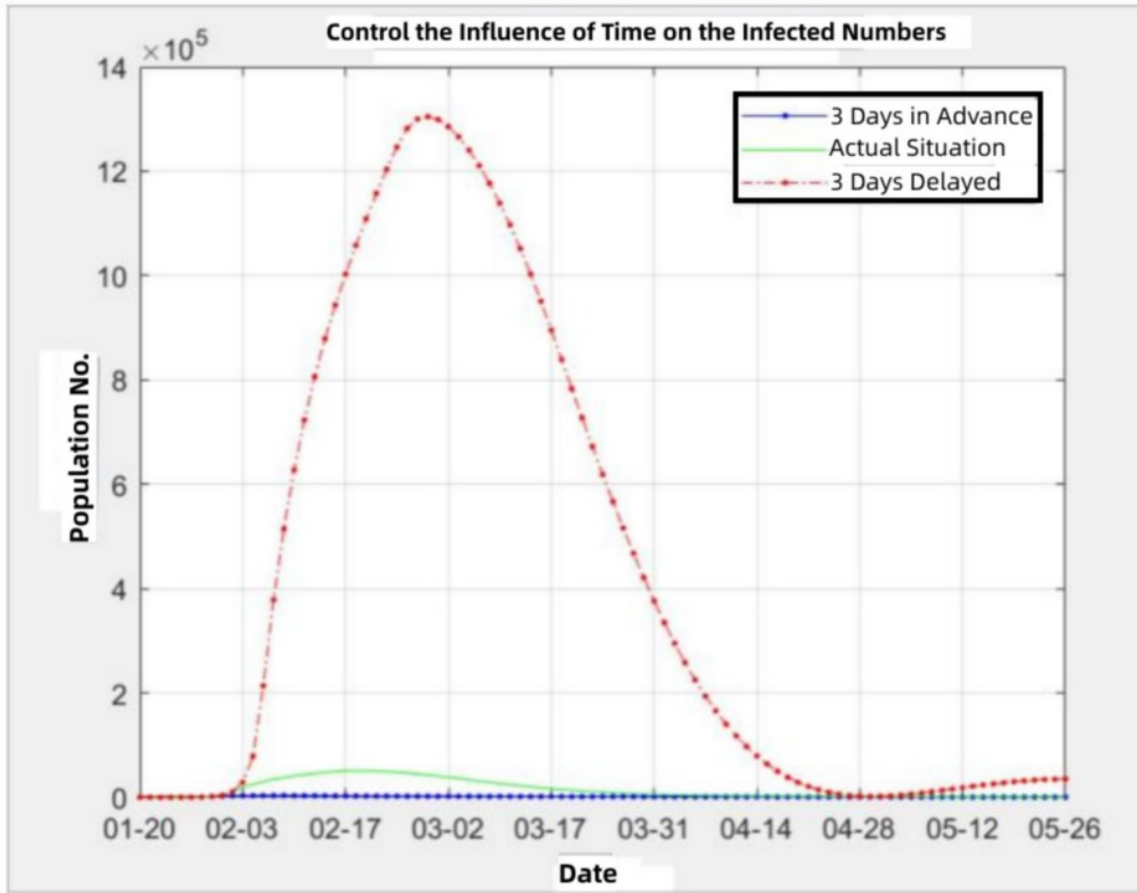


Fig.7 Number of patients at different control times

It can be seen from Fig.7 that the advance or delay of control time has a significant impact on the prediction results of the model. Three days in advance can quickly control the epidemic, but if the control time is delayed for three days, the number of infections will greatly increase and the epidemic may rebound in the later stage, which is very unfavorable to the national control of the

epidemic. Control time has a great impact on the development of the epidemic, so prevention and control measures should be taken in advance to prevent the spread of the epidemic.

② The influence of isolation strength on the model

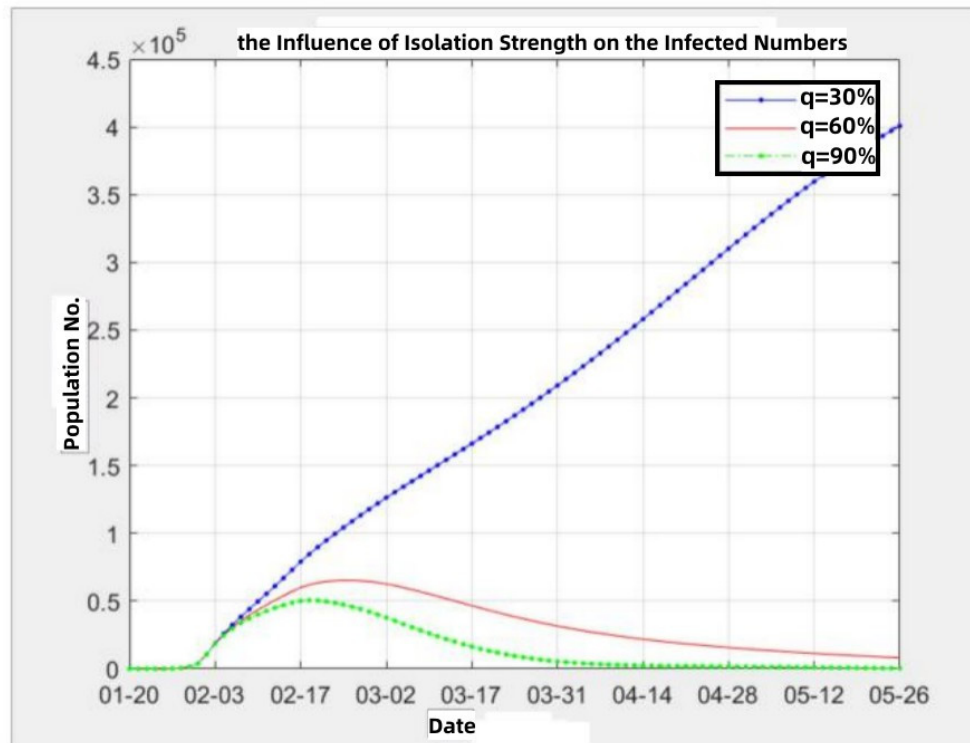


Fig.8 Number of patients under different isolation intensities

Fig.8 shows that the isolation intensity has a significant impact on the prediction results of the model. When the isolation intensity is 30%, the number of patients keeps increasing, which hardly hinders the development of the epidemic. The higher the isolation intensity is, the fewer the number of patients will be. Therefore, the isolation intensity should be increased in the process of epidemic prevention and control.

4. Analysis and forecast of COVID-19 in the United States

4.1. Data Acquisition

4.1.1 Index selection

This paper mainly selects the total number of confirmed infected cases and mortality of COVID-19 in Michigan in 2020 in a period of time (2020.3.14-2020.4.14) as the research object. In the simulation prediction based on the infectious disease model, the number of confirmed cases and removed cases is mainly predicted.

4.1.2 Data Source (Michigan, USA)

This paper uses the outbreak data mainly from Michigan and domestic government web site (https://www.michigan.gov/coronavirus/0,9753,7-406-98163_98173-,00.HTML). The data source is authoritative and effective.

4.2. The SIR dynamic model

The SIR dynamic model with the transmission characteristics of COVID-19 is established, and the MATLAB platform is used for simulation to obtain the evolution results of susceptible people, infected people and removed people over time in the transmission of Coronavirus.

It shows that during the spread of COVID-19, the number of infected people showed a slow upward trend at the initial stage, began to increase rapidly from March 21 to March 26, 2020, and would reach a peak around March 26, with the maximum number of infected people reaching 3,060,000. As the number of people removed increases and the number of people with antibodies increases, the number of infected people will continue to decline and then slowly begin to decline until completely disappearing.

The peak number of infected people predicted by the above SIR model is 3,060,000, but the actual number of infected people in Michigan on March 26 was 13,173. The predicted peak data is much higher than the actual data, and the simulation experiment had a large error. The analysis shows that the SIR model does not take into account the infectivity of Coronavirus incubation period and the influence of human intervention factors, thus leading to a large deviation between the predicted results and the actual results.

4.3. Analysis of SEIR model prediction results

The SEIR dynamic model with the transmission characteristics of COVID-19 is established, and the MATLAB is used for simulation to obtain the evolution results of susceptible people, exposed people, infected people and removed people over time in the transmission of Coronavirus.

In this way, we got that in the transmission of coronavirus, the exposed cases showed a rapid growth from March 21, 2020 to March 24, 2020, while the infected people showed a slow growth in the early stage. The exposed cases showed a rapid growth from March 22, 2020 to March 27, 2020, and the peak value of the exposed cases was reached around March 24. The number of infected people reached the peak around March 27, after which the number of exposed people and infected people began to decrease gradually until both of them were eliminated.

Due to the initial lack of attention to the epidemic in the United States, although confirmed infected cases appeared in various places at the beginning of the epidemic, the number of hospitalized infected people was very small and even not recorded until April 9, 2020. Therefore, we regarded the number of cured patients from March 14 to April 14 as 0. Compare the actual data with the predicted data.

It shows that the prediction result of the COVID-19 epidemic by using SEIR model is not ideal. The predicted number of infected people removed people (died or cured) are far higher than the actual data.

In fact, there is no peak in the actual data, and the number of infections has been continuously increasing, which is related to the lack of attention to the COVID-19 epidemic in the United States. Therefore, the SEIR model needs to be improved to suit the situation in Michigan.

4.4. Analysis of prediction results of improved SEIR model

4.4.1. Index Selection

This paper mainly selects the total number of confirmed infected cases and deaths of COVID-19 in Michigan in the period immediately after the outbreak of COVID-19 in 2020 (2020.3.14-2020.4.14) as the research object. In the simulation prediction based on the infectious disease model, the number of confirmed infected cases and the removed cases (cure and death) are mainly predicted.

Since the US government did not pay much attention to the disease or take relevant measures in time after the outbreak, the model was re-adjusted and death cases were added for analysis, and the new differential equation is obtained as follows:

$$\begin{cases} \frac{dS}{dt} = -r[\beta_1 E + \beta_2 I] \frac{S}{N} \\ \frac{dE}{dt} = r[\beta_1 E + \beta_2 I] \frac{S}{N} - \alpha E \\ \frac{dI}{dt} = \alpha E - (\gamma + \theta) I \\ \frac{dR}{dt} = \gamma I \\ \frac{dD}{dt} = \theta I \end{cases} \quad (22)$$

After the above differential equation is differentiated, MATLAB is used to solve the difference equation, and its difference form is as follows:

$$\begin{cases} S(i+1) = S(i) - r(\beta_1 E(i) + \beta_2 I(i)) S(i) / N \\ E(i+1) = E(i) + r(\beta_1 E(i) + \beta_2 I(i)) S(i) / N - \alpha E(i) \\ I(i+1) = I(i) + \alpha E(i) - (\gamma + \theta) I(i) \\ R(i+1) = R(i) + \gamma I(i) \\ D(i+1) = D(i) + \theta I(i) \end{cases} \quad (23)$$

Each parameter value is consistent with the above parameter value. The infected and the dead are separated and compared with the actual data. MATLAB platform is used for simulation to obtain improved model prediction results. The results are shown in Fig.9 and Fig.10:

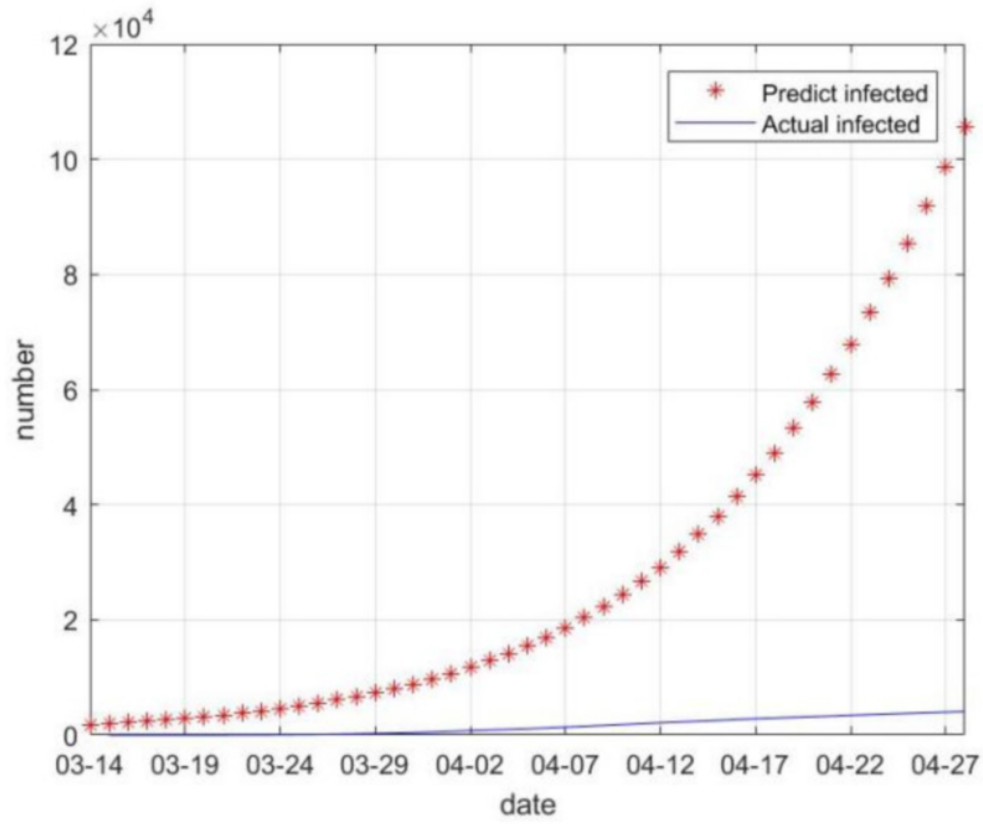


Fig.9 Comparison of infected people in the improved SEIR model

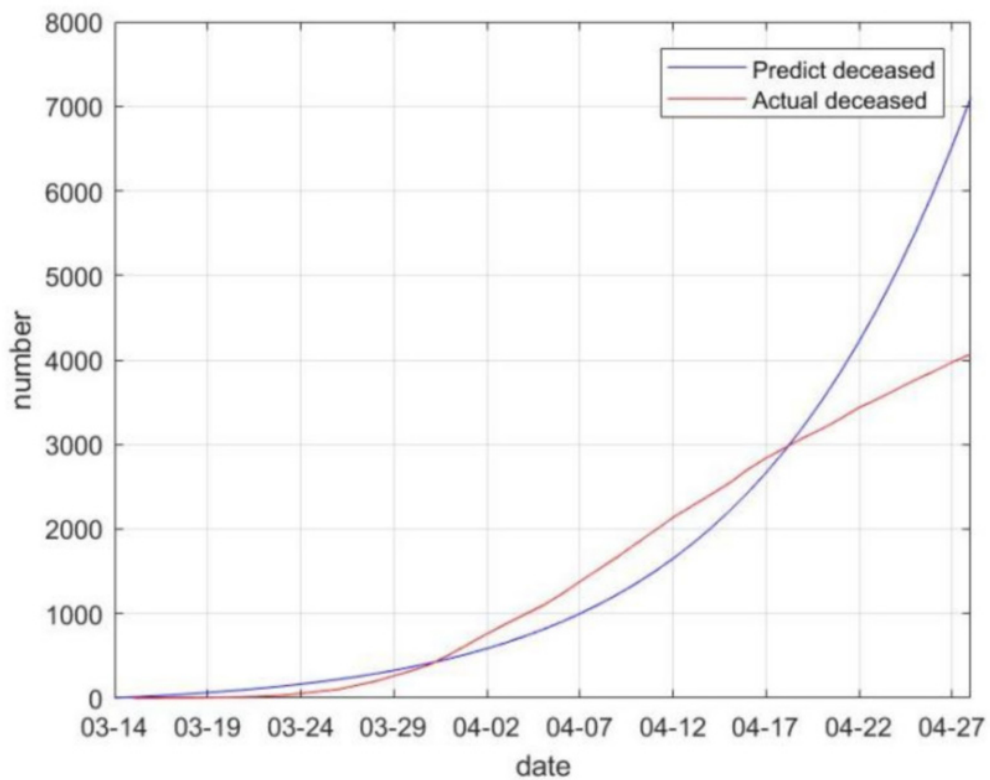


Fig.10 Comparison of the dead in the improved SEIR model

Through Fig.9 and Fig.10, we can see deviation between predicted infection number and actual infection number in the early period is small. But after that stage, the prediction is greater than the actual infection number. Considering people at the beginning are not clear about the dangers of infectious disease and paid less attention on it, while with the surge of infected population, they began to pay close attention to the disease, reduced their contact with the outside world, enhanced sanitation measure, and the Michigan state government has also taken actions to limit gatherings and emphasize safety and hygiene, the predicted value is reasonably higher than the actual value.

5. Conclusion

Based on the prediction of Wuhan and Michigan, it can be found that the two countries have adopted different prevention and control measures in the severely affected areas. The effective prevention and control countermeasures are found from the prediction analysis and comparison of the model.

5.1 Quarantine and prevention

Quarantine and prevention measures, such as "city lockdown" and "closed community", are taken to reduce the number of contacts of exposed people and infected people. If the corresponding isolation measures are not taken, the consequences will be more serious with the increase of contacts. After quarantine, the number of contacts between exposed people and infected people decreased. Strict quarantine measures are the most effective method for epidemic prevention and control. Quarantine measures can reduce the number of contacts, but the quarantine intensity is also crucial to the spread of infectious diseases. The number of infected people varies greatly under different quarantine intensities.

5.2 Timely deployment

The time for taking measures plays a key role in epidemic prevention and control. If the measures are delayed for three days, the number of infected people will greatly increase and the epidemic may rebound in the later stage. If the quarantine measures are deployed three days in advance, the number of infected people will be greatly reduced.

5.3 Personal protection

In non-severe areas, the quarantine intensity is not as high as that in Wuhan, and the number of contacts r is large. Therefore, daily personal safety protection is extremely important. The probability of susceptible persons being infected after contact with exposed people and infected people is closely related to the importance of personal safety protection. Individuals should pay

attention to protection in daily life, such as wearing masks, keeping a safe distance of 1 meter when queuing, and measuring their body temperature in time. People in Michigan did not realize the high infection rate of COVID-19 and paid little attention to personal protection, so the infection rate was higher than that in China, which also contributed to the increase in the number of new infections in Michigan.

5.4 Rapid resource mobilization

The probability of recovery of infected persons also has an important impact on the end of the epidemic, in addition to the timely treatment of individual immunity will also effectively increase the recovery rate. Therefore, rapid mobilization of medical resources, rapid delivery of medical resources to severely affected areas, and ensuring local people's access to effective medical resources are important measures for COVID-19 prevention and control.

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