Simulation of Spreading COVID-19 by Using Extended SEIR Model with Unconfirmed Cases and Death Toll

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1. Introduction

Currently, COVID-19 is spreading all over the world, and the number of confirmed cases is increasing day by day. Then, SEIR model is applied for prediction of spreading COVID-19. However, because of existing asymptomatic infected people and limited number of testing, there is a difference between the number of confirmed cases and infectious people. In addition, it is important to consider the death toll of the epidemic, not only the infection cases. In this study, we extend SEIR model considering confirmed cases, unconfirmed cases and death toll.

2. Proposed Method

We propose this extended SEIR model (Fig. 1). It is considered both confirmed and unconfirmed cases for the number of infectious, recovered and death. The extended SEIR model can be described by Eq. (1). $S(t)$, $E(t)$, $I_u(t)$, $I_c(t)$, $R_u(t)$, $R_c(t)$, $D_u(t)$ and $D_c(t)$ mean populations of susceptible, exposed, infectious unconfirmed, infectious confirmed, recovered unconfirmed, recovered confirmed, death unconfirmed and death confirmed at time t, respectively. Then, β, ϵ_u, ϵ_c, γ, κ_u and κ_c mean infectious rate, onset rate for unconfirmed infectious, onset rate for confirmed infectious, recovered rate, death rate for unconfirmed infectious and death rate for confirmed infectious, respectively.

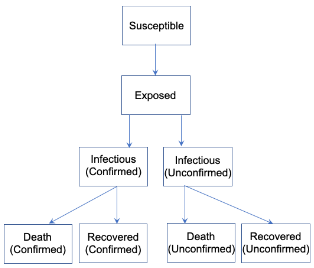

Figure 1: Structure of proposed model.

$$\begin{cases} \frac{dS}{dt} = -\beta S(t)\{I_u(t)+I_c(t)\} \\ \frac{dE}{dt} = -\beta S(t)\{I_u(t)+I_c(t)\} - (\epsilon_u+\epsilon_c)E(t) \\ \frac{dI_u}{dt} = \epsilon_u E(t) - \gamma I_u(t) - \kappa_u I_u(t) \\ \frac{dI_c}{dt} = \epsilon_c E(t) - \gamma I_c(t) - \kappa_c I_c(t) \\ \frac{dR_u}{dt} = \gamma I_u(t) \\ \frac{dR_c}{dt} = \gamma I_c(t) \\ \frac{dD_u}{dt} = \kappa_u I_u(t) \\ \frac{dD_c}{dt} = \kappa_c I_c(t) \end{cases} \tag{1}$$

In addition, we calculate new confirmed cases of infectious people $N(t)$ by Eq. (2).

$$N(t) = \frac{I_c(t)}{\gamma} \tag{2}$$

3. Simulation Result

Parameters that we use are shown as follows: β=0.26, ϵ_u=0.18, ϵ_c=0.02, γ=0.09463, κ_u=0.00004884, κ_c=0.004884. Eq. (1) is solved by the Runge-Kutta method. Figure 2 shows the simulation results.

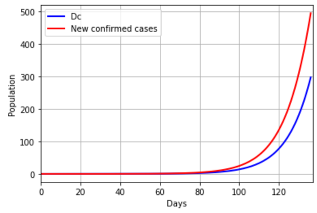

Figure 2: Simulation results of the proposed model.

Figure 3 shows real new confirmed data of infectious people in Tokyo.

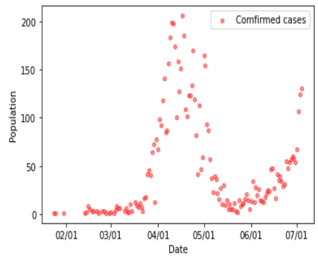

Figure 3: Real data of new confirmed cases of infectious people.

There is the difference between simulation result and real data, especially the shapes of graphs. It is because of the characteristic of SEIR model. SEIR model can express only one wave of infections when parameters are constant. Therefore, the simulation result does not fit with the real data that has a part of second wave.
Figure 4 shows real confirmed death data in Tokyo.

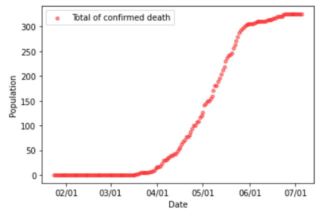

Figure 4: Real data of confirmed death cases.

Though there is the difference between simulation result and real data, real date plot of confirmed death cases fits the simulation data. According to the simulation, confirmed cases of death will be more than 6000 cases after 250th days.

4. Conclusion

In this study, we simulated the spreading COVID-19 in Tokyo with extended SEIR model. The simulation results were close to real data, but they did not fit enough. For future work, we will optimize simulation results by root mean square error.