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Modeling on Social Spread from Immunity

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SUMMARY: We are now planning to make a transmission model of infectious diseases in the scale of a city. People live in the city contacting other persons with daily life. The model regards a contact as a source of infection. A person will be simulated as a simple system of differential equations. As a candidate of differential equations, we are now investigating Marchuk's simple model. We adopt Marchuk's simple model because it has formation time, i.e., latent time. As Dr. Takeuchi showed, latent time is very important. There remain problems of choosing parameters for special diseases. We are now planning to use Marquardt method to minimize residuals form clinical data to estimate parameters. As for contacts, there are many approaches. The approach of the MIDAS project is very intensive. Our approach is simple. There are about 30,000 Japanese every fifteen minutes daily life data, sleeping, eating, work, study, house keeping, etc. Our approach is to make virtual families, husband, wife, children in a city and assign actions from the every fifteen minutes data statistically and estimate their contacts in the companies or schools, etc.

We simulated the spread of infectious disease based on the contact model of Japanese people. We also simulated an immune response of a person to get the parameters for the model of contacts of people. When a cold or influenza prevails in winter, schools are shut down in Japan. We investigated the effect of this strategy by simulations of our model.

Immune response

We simulated an immune response of a person as a system of differential equations using Marchuk's simple model (1) shown below. We adopt Marchuk's simple model, because it has formation time, i.e., latent time, one of key factor of infection.

$$\frac{d}{dt}\begin{pmatrix} V \\ C \\ F \\ m \end{pmatrix} = \begin{pmatrix} (\beta - \gamma F)V \\ \xi(m)\alpha V(t-\tau)F(t-\tau) - \mu_c(C - C^*) \\ \rho C - (\mu_f + \eta\gamma V)F \\ \sigma V - \mu_m m \end{pmatrix}$$

where V(t): concentration of pathogenic organ, F(t): concentration of antibodies, C(t): concentration of plasma cells, m(t): relative characteristic of affected organ, β: multiplication, γ: neutralized, τ: formation time, α: antigen-antibody collision *: constant level, μ: life time, ρ: production, η: efficiency, ξ: function of m.

We set 3 days as the parameter of latent time after our experience. The remains of parameters are decided referring a study of pneumonia (2). We used Runge-Kutta method to simulate this delayed differential equations. Period of infection is also an important parameter to make a model. We decided the parameter by the simulation of an immune response. We set 7 days as the period of infection based on the simulations and this coincides with our experiences.

Contact model

People live their lives contacting other persons and infectious diseases spread by contacts. As for infection by contacts, there are many approaches (3-6). The MIDAS project employed a very intensive agent technology to model contacts (7). We used a statistics of Japanese daily life. The statistics is about every 15 minutes actions of daily life of 30,000 Japanese, such as sleeping, eating, work, study, house keeping, etc. (8). Our approach is to make virtual families, i.e., husbands, wives, children in a city, assign their behavior by Monte Carlo method according to the statistics and estimate their contacts in the companies or schools, etc.

Simulation

We assumed 1,000 persons living in a small city and infection spread from a specified family consists of three persons. As for infection, latent time is 3 days and people get infected for 7days and recovered. Infection is not severe, so infected people do not change their behaviors. Infection rate of simulation is assumed as 1%, 10%, 20% and 50%.

In the case of 1% infection prevailed for the longest and the total number of infected people is not so small compared

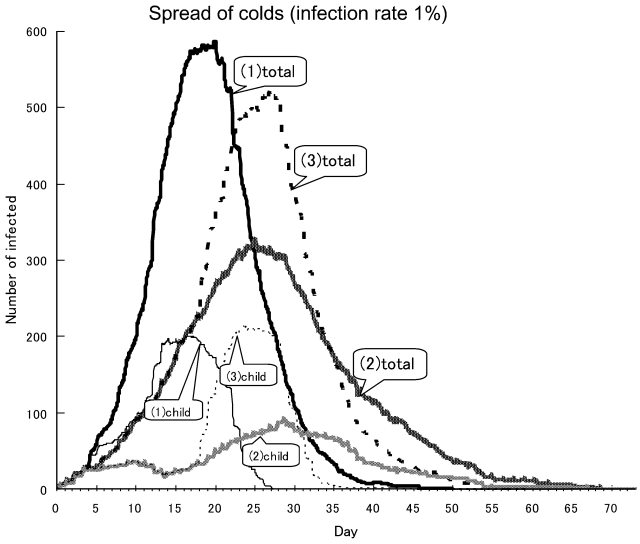

Fig. 1. Number of infected persons in case of infection rate is 1%. (1) Original case, (2) Schools were shut down after 4 days, (3) Schools were shut down after 4 days and opened after 13 days from shutdown. Total numbers of case of (1), (2), (3) are 216,408, 190,488, 217,128 and total numbers of case of (1) child, (2) child (3) child are 63,528, 52,968, 63,528.

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to other cases.

When schools were shut down after 4 days from the outbreak, the peak of infected is decreased but the period of infection is prolonged.

As for children, in case of infection rate is 1%, the total number decreased 17% compared to the original case.

We also simulated the case that schools are opened again after 13 days from school shutdown in infection rate 1%. As for children, the total number does not decrease compared to the original case. The peak of the graph does not decrease also, it only shifted later. This is shown in Fig. 1, graph (1) means original case, graph (2) means the case that schools are shut down after 4 days from outbreak, graph (3) means the case that schools are shut down after 4 days from outbreak and opened again after 13 days from school shutdown.

According to our simulations, strategy of (3) did not improve the situation and the results of (2) showed that the effect of school shut down is not so big.

Our model is simple, but validation is not done well. Professor Koopman cautioned simple models as follows (9). Do not ignore detail and realistic aspect of data. But we can do many parameter runs not only in moderate case but also in extreme cases because of simplicity of the model. Robustness will be gained comparing the results.

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