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Anti Pandemic Simulation by SOARS

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Abstract

Next pandemic caused by human to human outbreak of mutated H5N1 bird flu is almost inevitable. To prevent the pandemic we must take steps not only from medical point of view but also from social program point of view. In this paper we propose four categories of social protection programs. We modeled the infection process under the social activities of agents by using SOARS (Spot Oriented Agent Role Simulator). We evaluated the effectiveness of the social programs to protect the pandemic by agent based simulation. As a result we found that there exists a critical bifurcation point between eradication and spreading by controlling the combination of social protection program.

Keywords: Pandemic, H5N1 bird influenza, SOARS, Grid Simulation

1. Introduction

In this paper, we have developed a basic model of social simulation for protecting pandemic caused by human to human outbreak of mutated H5N1 bird influenza. We divide our model to three basic models. The one is a stage transition model of disease under the physical condition and medical treatment. The next is a contamination and infection module that contain six types of protection policy of contamination and infection. The third is a human activity module on a virtual city that contains several types of social activities of agents. We have distinguished several types of medical and social protection policy of infection and contamination of virus in the modules. We also have evaluated the protection policy from the viewpoint of program and project management. As a result, we point out the importance of the four types of social protection policies except vaccination and anti virus drugs. That is to say the excretion control policy by free mask, the attenuation control policy by humidity and sterilization control of spot, the self protection policy of by N95 mask and the space density control policies by several approaches such as flex time work to control overcrowded train or bus, space density control in classroom, office, hospital and family life style.

We assume that the social protection filter is composed of the combination of these four types of social protection policies. The strength of social protection filter is defined as the product of the strength of four protection policies. Then we have shown by agent based simulation via SOARS that the bifurcation of the steady state of the infection process in a society only depends of the strength of social protection filter in the society. We have analyzed the land scape of the bifurcation using SOARS potable grid for simulating the model.

For analyzing infection and contamination process there are several types of mathematical and simulation models. The sir model and its variations are basic one that treat macro process of infection but omit social activities of agents. The percolation model treats infection process as statistical point of view. It provides the information of critical probability for spreading of infection to the hole system. Contact process model with diffusion process provides statistical infection dynamics. However, the assumptions for these types of models are hard to describe infection and process under the social activities. The agent based approach gives another way of modeling method [Axelrod, 1997]. The agent based simulation is sometime called the individual approach. The epidemic model of agent based modeling is developed by K. Carley, at C.M.U and Epstein at Brooking Institution [Carley, 2003; Epstain, 2004]. The former treats the infection by "Anthrax" depending on her agent based simulation with a social network of agents. The later treats the infection by smallpox on the cell based model of agent simulation. The protection policies investigated on these types of agent based approaches include vaccination, isolation and blockade. These types of policies are connected to agent activities in the societies. The network type model of agent based simulation was originally developed by K. Cerley and her group <www.casos.cs.cmu.edu/projects/biowar/ index.html>. It is useful for concise description of complex activities in the big cities. The approach was introduced by the followers.

The cell type model is basic and intuitive. Then it is widely used. In the simulation model of emerging influenza pandemic in Southeast Asia they use the cell type model for analyzing the effectiveness of "Oseltamivir (Tamiflu)" [Ferguson, 2005]. We have introduced another type of model for agent based approach. We introduce the concept of spot that is a place on which agents interact. Agents also move among spots depending on their social roles. We do not assume special topology such as 2 dimensional lattice among the spots. Spots stand for home, office, office room, school, classroom, hospital, ward, bed, consulting room, car,

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train, shop and other social places depending on the model scope and subdivision of the model. We have developed the agent based simulation framework called SOARS (Spot Oriented Agent Role Simulator) for analyzing agent based epidemic simulation of SARS [Deguchi, 2004]. Now SOARS is developing as an agent based social simulation language and visual programing framework for domain expert. We use SOARS for our pandemic simulation framework<www.cs.dis.titech.ac.jp/en/>.

In our model, we treat contamination of spots and agents and infection of agents. We also deal with medical treatment and its effect for disease stage transition. For the purpose, we introduce three different types of modules in our model. The one is a stage transition model of disease under the physical condition and medical treatment. The next is a module for contamination and infection that contains six types of protection policies of contamination and infection. The third is a human activity module on a virtual city that contains several types of social activities of agents. We have distinguished several types of medical and social protection policy of infection and contamination of virus in the modules. Our model is not limited to influenza case. It provides general epidemic model of contamination and infection under the social activities of agents. Our model is not limited to special type of city structure or agent roles. For applying our model to specific case we have to modify the modules depending on intended cases. In this paper, we treat emerging influenza case.

In our model, we do not treat elimination policy of virus. Instead, we propose several types of socioeconomic policies that minimize the number of infected and dead persons.

2. Stage Transition Model of Disease

A state transition module gives stage transition structure of agents under the condition of age, vaccination and medical treatment such as AntiVirus drugs. We divide agents into several categories by age and vaccination first. We use five categories of age such as b: baby, c: child, y: young, m: middle, o: old. We consider two types of vaccination such as influenza vaccination for all age and pneumonia vaccination only for old age. One type of medical treatment is also assumed in our model such as anti-virus drugs. Stages for disease are expressed as 0, 1,2,2m, 3,3m, 3s, 3p, 4c, 4m, 5, D and 0i. 0 denotes no infection. 1 denotes the first stage of infection. We assume a little excretion of virus at this stage. In the second stage denoted by 2, an agent has high fever. The excretion of virus is large. 2m denotes second but mild stage where the fever is slight. In the third stage denoted by 3, the excretion is very large. 3m denotes third but mild stage. 3s denotes third and severe stage. 3p denotes third stage with additional infection of pneumonia. 4c denotes forth and critical stage. 4m denotes forth and mild stage. 5 denotes recovery stage and D denotes death stage.

Level of virus excretion is expressed in the model not by the number of virus but by excretion scale between 0 and 1. The stage model gives the excretion scale in each stage as is shown in the table 1.

Table 1 Disease Stage Model of Influenza

Stage	Explanation	Period	Excretion	Scale
0i	Recovery with immunity		No	0
1	First Stage	2 days	little	0.2
2	Second Stage: high fever	2 days	large	0.6
2m	Second Mild Stage: slight fever	2 days	little+	0.4
3	Third Stage: feaver	2 days	large+	0.8
3m	Third Mild Stage: slight feaver	1 day	medium	0.5
3s	Third Severe Stage	3 days	large	0.6
3p	Third Pneumonia Stage	3 days	large	0.6
4c	Fourth Critical Stage	3 days	medium	0.5
4m	Fourth Mild Stage	3 days	medium	0.5
5	Fifth Recovery Stage	2 days	little	0.2
D	Death		No	0

We also define transition probability between stages under certain physical condition such as age and vaccination and medical treatment by anti virus drugs. The probability is shown in the table 2.

Table 2 Stage Transition Model (Part)

Age	Influ. Vacc.	Pneu. Vacc.	Disease Stage	Tran. Prob.	Disease Stage	Treat	Tran. Prob.	Disease Stage	Tran. Prob.	Disease Stage	Tran. Prob.	Disease Stage	tran. prob.	Disease Stage	Day	prob.	Prob. Sum.
b,y,c,m	No	No	1	0.8	2	-	0.8	3	1	5	1	0i			8	0.64	
b,y,c,m	No	No	1	0.8	2	-	0.2	3s	0.8	4m	1	5	1	0i	12	0.128	
b,y,c,m	No	No	1	0.8	2	-	0.2	3s	0.2	4c	1	D			10	0.032	0.8
b,y,c,m	No	No	1	0.8	2	Treat	0.5	3m	1	5	1	0i			7	0.4	
b,y,c,m	No	No	1	0.8	2	Treat	0.4	3	1	5	1	0i			8	0.32	
b,y,c,m	No	No	1	0.8	2	Treat	0.1	3s	0.8	4m	1	5	1	0i	12	0.064	
b,y,c,m	No	No	1	0.8	2	Treat	0.1	3s	0.2	4c	1	D			10	0.016	0.8
b,y,c,m	No	No	1	0.2	2m	-	1	3m	1	5	1	0i			7	0.2	0.2
o	No	No	1	0.9	2	-	0.6	3	1	5	1	0i			8	0.54	
o	No	No	1	0.9	2	-	0.4	3s	0.8	4m	1	5	1	0i	12	0.288	
o	No	No	1	0.9	2	-	0.4	3s	0.2	4c	1	D			10	0.072	0.9
o	No	No	1	0.9	2	Treat	0.4	3m	1	5	1	0i			7	0.36	
o	No	No	1	0.9	2	Treat	0.4	3	1	5	1	0i			8	0.36	
o	No	No	1	0.9	2	Treat	0.2	3s	0.8	4m	1	5	1	0i	12	0.144	
o	No	No	1	0.9	2	Treat	0.2	3s	0.2	4c	1	D			10	0.036	0.9
o	No	No	1	0.1	2m	-	1	3m	1	5	1	0i			7	0.1	0.1
b,y,c,m	Yes	No	1	0.5	2	-	0.8	3	1	5	1	0i			8	0.4	
b,y,c,m	Yes	No	1	0.5	2	-	0.2	3s	0.8	4m	1	5	1	0i	12	0.08	
b,y,c,m	Yes	No	1	0.5	2	-	0.2	3s	0.2	4c	1	D			10	0.02	0.5
b,y,c,m	Yes	No	1	0.5	2	Treat	0.5	3m	1	5	1	0i			7	0.25	
b,y,c,m	Yes	No	1	0.5	2	Treat	0.4	3	1	5	1	0i			8	0.2	
b,y,c,m	Yes	No	1	0.5	2	Treat	0.1	3s	0.8	4m	1	5	1	0i	12	0.04	
b,y,c,m	Yes	No	1	0.5	2	Treat	0.1	3s	0.2	4c	1	D			10	0.01	0.5
b,y,c,m	Yes	No	1	0.5	2m	-	1	3m	1	5	1	0i			7	0.5	0.5

3. Contamination and Infection Model

We introduce the several types of virus protection policies in our contamination and infection model on the

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small city model. Total model structure of contamination and infection process is shown in figure 1.

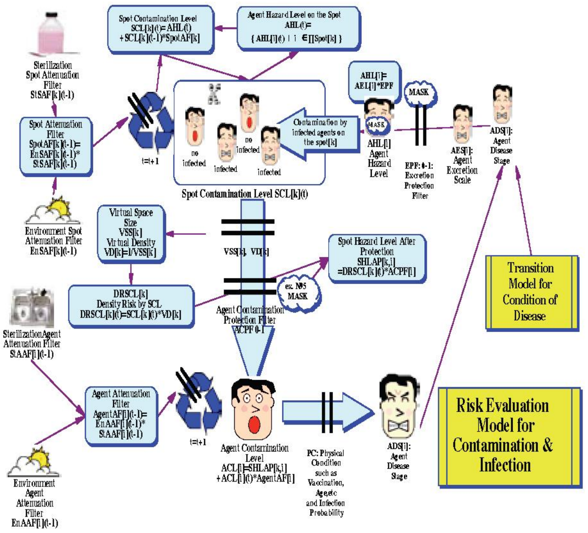

Figure 1 Virus Contamination and Infection Model

We assume that the following contamination and infection process. An infected agent has the excretion scale level depending on his disease stage. The agent visits a certain spot. Then the agent might use excretion protection filter such as a mask. Agent hazard level for the spot is defined by the excretion scale and whether the agent is using excretion filter or not. AHL[i] denotes Agent Hazard Level of an agent [i] that is defined as AHL[i](t)=AES [i](t)*EPF[i](t) where AES[i] denotes Agent Excretion Scale of agent [i] and EPF [i] denotes the level of Excretion Protection Filter. EPF[i] means the effectiveness of the mask if an agent [i] is using a mask. Total hazard level of a spot [k] is shown as AHL [k]=Σ{AHL[i] | i∈Spot[k] }. Where AHL[k] denotes total agent hazard level of agents who exist in a spot [k]. Spot Contamination Level of a spot [k] is denoted by SCL[k](t) that is determined by AHL[k](t): the agent hazard level of a spot [k] at the present step, SCL[k](t-1): the spot contamination level at the previous step, and SpotAF[k](t-1): Spot Attenuation Filter at the previous step as follows. SCL[k](t)=AHL(t)+SCL[k](t-1)*SpotAF[k](t-1). SpotAF[k] denotes the attenuation scale for the previous spot contamination. SpotAF[k] is determined as SpotAF[k](t)=EnSAF[k]*StSAF[k] where EnSAF[k] denotes Environmental Spot Attenuation Filter that is affected by the seasonal changes of climate or controlled humidity in the spot. StSAF[k] denotes Sterilization Spot Attenuation Filter that is controlled by sterilization of the spot. The process is shown in figure 3.

Spot contamination causes the contamination of each agent. Then an agent will be infected depending on his physical condition. In our model inter agent infection is divided into such sequential process as the spot contamination by the infected agents, the agent contamination by the contaminated spot and the agent infection by his own contamination. The model becomes equivalent to direct infection model among agents at a spot if we omit attenuation factors.

We introduce two types of protection policies that can be used while a spot contamination affects to an agent contamination. The one is called the virtual space density control or simply the density control. The density means contact density among agents in a spot. The density is affected by both the activity pattern and physical space size among agents. To know the detailed activity pattern of agents we have to construct an activity model detail to the second. It is not realistic to make such a detailed model. Instead, we introduce the concept of virtual space density. The density can be evaluated by an actual social experiment. The virtual space density of home depends on the cultural life style and the family structure. The virtual space density is an easier factor to control socially. For example, we can control the virtual space density in a classroom of a school by leaving more space among the desks. We can also control the virtual space density in a train by stagger office hours. The other protection policy is called the personal contamination protection by an agent such as wearing N95 mask that is effective for the protection against virus.

Then the density risk (DRSCL[k]) by the spot contamination level(SCL[k]) is defined as DRSCL[k](t) =SCL[k](t)*VD[k]. Where VD[k] denotes the virtual density of a spot[k]. Agent Contamination Protection Filter(ACPF[i]) denotes the effectiveness of the above way of contamination protection by an agent[i]. Spot Hazard Level After Protection by an agent[i] at a spot[k] (SHLAP[k,i]) is defined as SHLAP[k,i]=DRSCL[k](t) *ACPF[i]. The relation is shown in Figure 4.

Agent Contamination Level(ACL[i]) is defined as is shown in the definition of SCL[k] as follows. ACL[i](t) =SHLAP[k,i](t) +ACL[i](t-1)*AgentAF[i](t-1). Where Environment Agent Attenuation Filter (EnAAF[i]), Sterilization Agent Attenuation Filter (StAAF[i]) and Agent Attenuation Filter:AgentAF[i]=EnAAF[i]*StAAF [i] are defined as the same way.

Then the infection possibility of an agent is defined as follows.

P(infection of agent [i] per Step)=1-exp(-FP*TP*ACL [i]). Where TP is called the tick parameter that adjusts the selection of time scale in the simulation. FP(Fitting Parameter) denote a parameter for the total calibration of our model.

4.Agent-based Simulation by SOARS

SOARS is an agent based simulation language and its application development environment. SOARS

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was developed at Deguchi Laboratory under the COE program of Tokyo Institute of Technology<www.absss.titech.ac.jp/en/>, <www.cs.dis.titech.ac.jp/en/>. SOARS supports a simple PC cluster construction kit that is called Soars Portable Grid. Figure 2 & 3 shows SOARS Launcher and SOARS Visual Shell model respectively.

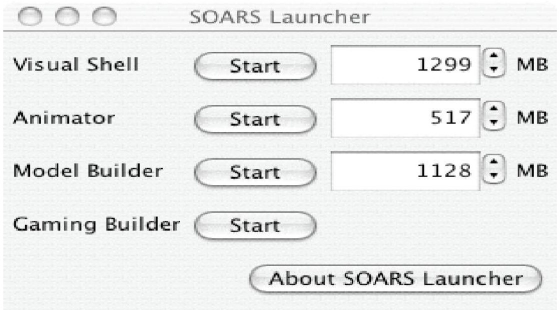

Figure 2 SOARS Launcher

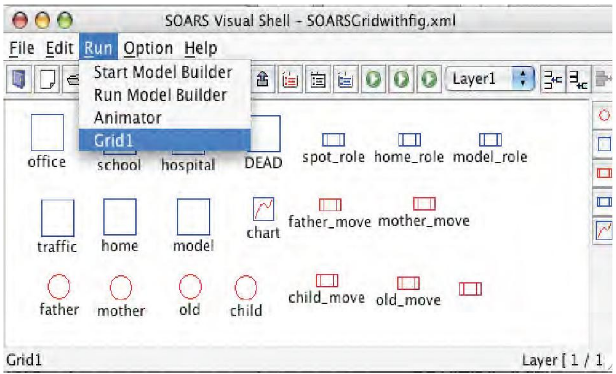

Figure 3 SOARS Visual Shell Modeling

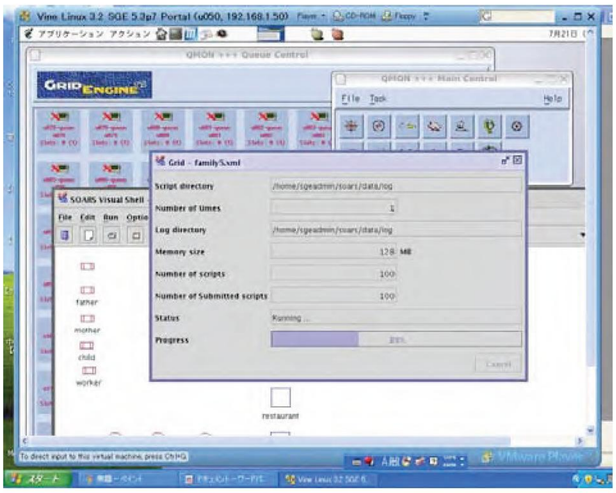

Figure 4 SOARS Portable Grid

Figure 4 shows the simulation of our pandemic model by using soars portable grid. Figure 5 shows SOARS total simulation environment.

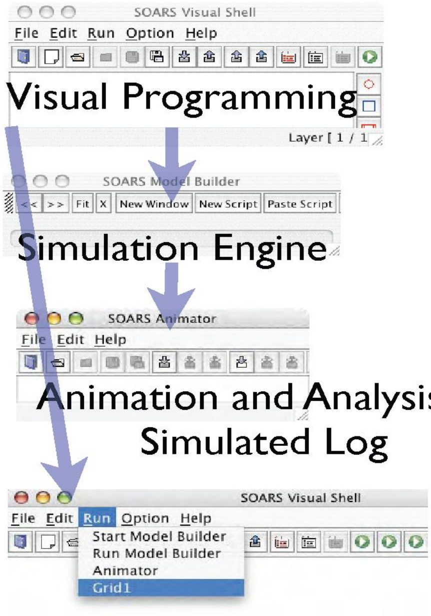

Figure 5 SOARS Simulation Environment

5. Human Activity Model & the Combination of Models

We also assume a human activity scenario of how agents move among spots in the society or are isolated in the hospital. In our test model, there are 200 families of 800 agents in the virtual city. Figure 6 shows human activity model in the virtual city.

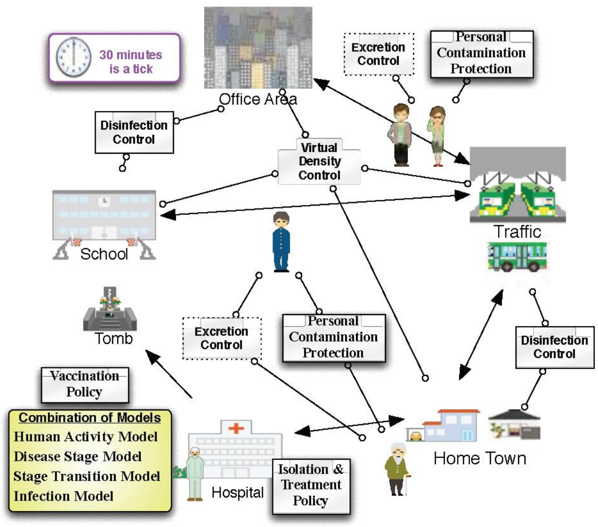

Figure 6 Human Activity Model

There are several types of spots in the city such as traffic, office, school, hospital and homes. We assume a simple activity of agents. An adult agent goes to the office every morning from the own home via traffic and comes back to the home late evening. A student goes to school every

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morning and comes back to the home early evening. Old agents stay homes in this model. If the agents are infected and become stage 2 then they go into the hospital. But, if the stage become 2m then the agents do not go to the hospital for the isolation. The agents in the hospital go back to the homes and return to their daily lives if they become healthy with immunity that is represented by stage 0i.

We evaluated the effect of the social protection filters consist of humidity control policy (environmental spot attenuation filter), the virtual space density control policy, the excretion protection filter policy and the agent contamination protection filter policy. Total strength of the social protection filters is defined as the product of each protection filters. This is our essential hypothesis. These social protection filters construct a multi dimensional parameter space of protection policies. We have introduced the one dimensional protection policy space as the product of parameters and evaluated the effectiveness of the one dimensional protection policy by our agent based simulation model on SOARS.

In this model the effectiveness of the social protection filters is defined as the product among the weighted average level of virtual density of the spots (VD), the average level of environmental spot attenuation filter (EnSAF), the average level of excretion protection filter (EPF) and the average level of agent contamination protection filter(ACPF). We call the product the social protection filter. Notice that the effectiveness of the filter becomes better as the level of filter becomes close to 0. The effectiveness is also called the strength of the social protection filter. For simulating many combinations of social protection filters we used the SOARS portable grid that was developed by the SOARS project.

Time of one step (tick) is assumed to br 30 minutes. The simulation was done until the steady state of the number of the infected persons starting from initial five infected patients. Agents are moving among the spots every day. There is no vaccination and traffic blocking policy in this stage. Instead we introduce the policies of the social protection filters.

The effect of space density control is important to decrease infection ratio[Mangili,2005; Pijoan, 1997]. Humidity and temperature play important role for influenza virus survival[Harper,1969]. It is also pointed out in the case of SARS[Lin, 2006]. On the other hand there exists an epidemic of influenza in the tropics with high humidity. We can explain the fact from the existence of multi-critical parameters. Even if humidity is high, influenza spreads when the virtual space density of family is also high.

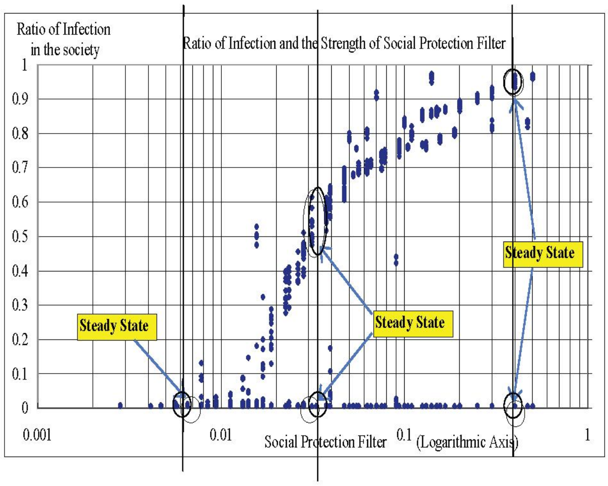

Figure 8 Bifurcation Landscape Analysis for Social Protection Filter Effect

Figure 8 shows the bifurcation landscape for the effect of social protection filter. X-axis shows the level of total social protection filter. Y-axis shows the infection ratio of the steady state in the simulated infection process. Each dot shows the steady state of the simulated infection process under the given level of social protection filter. We simulated 900 cases for 90 different scenarios of the combination of social protection filters. The simulation was done by SOARS potable grid. We found a typical bifurcation as was shown in the figure 8. We also found that the infection ratio of the steady state only depends the one dimensional level of the social protection filter in the society.

5. Conclusion

We developed an infection process model for pandemic depending on social simulation. We introduced three modules for this social simulation of pandemic protection. The one is the disease stage and stage transition model. The second is the infection process model. The third is the activity model on the virtual city. We combined these model components and introduced the social protection policies as the social filters. We evaluated the social protection policies on the combined model.

The traditional infection protection policy treats such critical parameters as vaccination, anti-virus drugs, isolation of patients, temporary closing of classes and the blocking of traffic to prevent infection. We have pointed out the importance of other social protection policies in the model such as the virus excretion control, the attenuation control of the contamination by sterilization and humidity, the virtual space density control and personal protection control. Most of these parameters are controlled socially. Our result suggests that the social control of multi-critical parameters in the infection process is essential to protect the pandemic.

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The effects of these parameters have been already analyzed independently[Dee,2005; Harper, 1961; Lin, 2006; Mangili,2005; Pijoan, 1997]. Agent based social simulation gives a total perspective and a process model that includes these social parameters. Of course we have to evaluate the effectiveness of each protection policy we have proposed in this paper and the crossing effect. For the purpose we have to develop new type of calibration method of the parameters in the agent based simulation. We also have to evaluate the cost performance of the combination of protection policies that depend on the social structure. Thus we introduce program and project management approach for pandemic protection. The pandemic protection program should include not only mthe edical and traditional virus protection policies but also the wide area of social protection policies that depend on the structure of the city and the society that is shown in Table 3 as examples.

Table 3 Social Virus Protection Policies

Target Cases	Purpose of Control	Measures for Project
School, Traffic,e.t.c.	Excretion Control	Free Mask at Public Space
Home, School, e.t.c.	Attenuation Control	Spread of Humidifier
Hospital, e.t.c.	Attenuation Control	Sterilization & Humidification
School, Office, e.t.c.	Virtual Space Density Control	Sheet Distance Arrangement
Hospital	Virtual Space Density Control	Bed Distance Arrangement
Family	Virtual Space Density Control	Activity Pattern of Family
Traffic	Virtual Space Density Control	Staggered Working, Gate Control
Traffic, Hospital, e.t.c.	Personal Protection Control	N95 Mask Vending Machine
School, Home, e.t.c.	Attenuation Control	Sterilization

Therefore we have to introduce the program and project management for social protection policy design depending on each social context. In order to organize social protection program for mutated N1H5 influenza under the context of each social condition, it is indispensable to introduce the protection program into the present influenza from next winter and evaluate the implementation program and the effectiveness. For the purpose epidemic analysis with social simulation can be used as shared internal model for planning, social informed consent and risk communication.

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