Small-world Model of Transmission of SARS

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Abstract

The model implements famous small-world network to simulate transmission of SARS in common people, using Swarm. The results successfully show the same diffuse trend as virus in real circumstance. Simultaneously, they show the most critical network parameters relating to the speed of transmission of the epidemic. In this model, I also discuss the effectiveness of the respective public health policies by importing some feedback mechanism.

1. Model Introduction

1.1 Algorithm of small-world network

Small-world networks lie between highly regular and thoroughly random networks. The strategy Watts uses to form small world network is to generate it from regular network with a probability of changing connections of its nodes. I adopt that in this model. Visualize process as below:

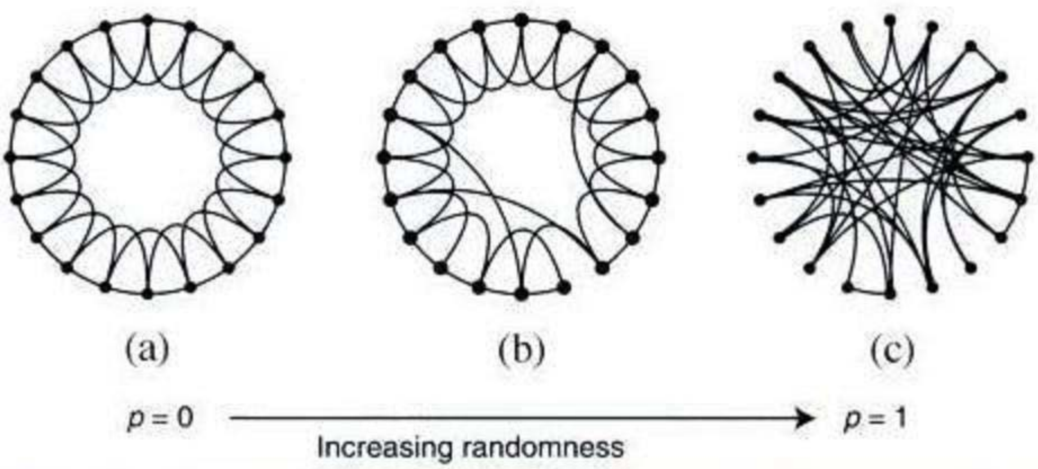


Figure 2. *Small world networks lie between highly regular and thoroughly random networks. Here the probability of rewiring each connection increases from 0 (a) to 0.1 (b) to 1 (c). (Reprinted with permission from* Small Worlds, *by Duncan J. Watts (1999), Princeton University Press.)*

Here are some parameters using in the model:

1. N----the number of nodes in the network;
2. K----the number of nodes that each node should be linked to;
3. p----the probability of reconnection (p=0, regular network; p=1, random network).

Parameters above should has relation as below:

$$N>K>\ln(N)>1$$

1.2 Mechanism of this model

Treat nodes as people and see connection between nodes as contact among people.
Suppose:

N=10000;
p=0.01.

Each agent has four states: Health, Latency, Infectiveness and Insulation.

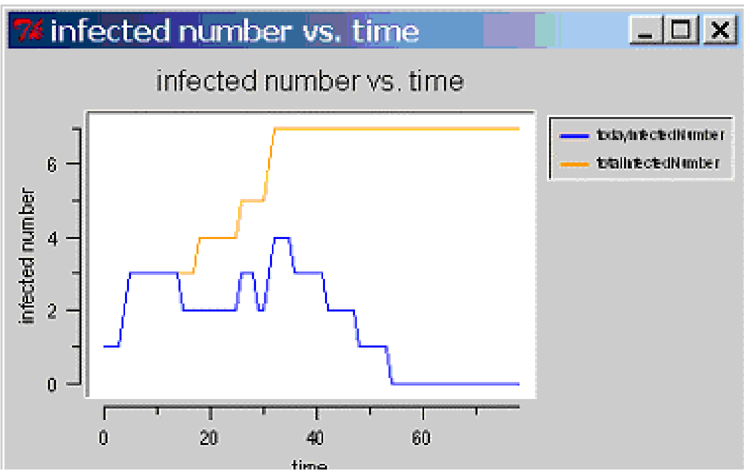
- Health
- Latency
  Individuals in latency state are not infective during this period.
  The time of latency obeys normal distribution (average=6, variation=4)
- Infectiveness: T
  T is a controllable parameter in this model.
  During infectiveness state, individual is infective. Any other agent who contacts with this node may have a probability of q to be infected and turn its state to Latency.
  Here， q obeys normal distribution (average=0.05,variation=0.0001)as well.
- Insulation
  Insulated time is 10 days.
  Each agent turns its state to Health when Insulation is done and enters circulation again.

2. Demonstration

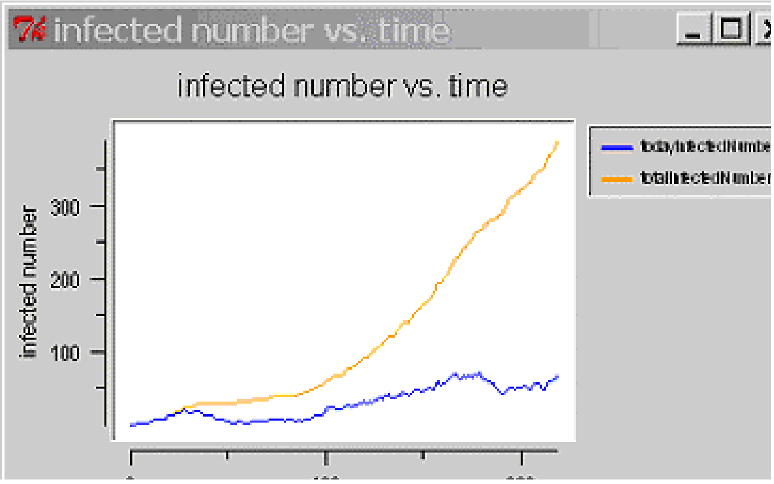
Adjust T & K according to real situation and observe what happens:
T----Representing the velocity of finding and insulating infective agents;
K----Representing compactness of these agents.

At the beginning, we make one agent infective, then let the system evolves freely. Record todayInfectedNumber and totalInfectedNumber each step.

2.1 No feedback mechanisms



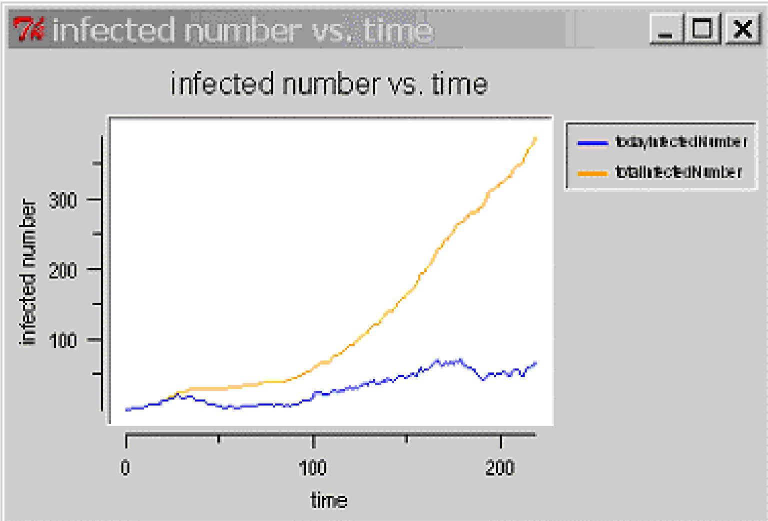
T=2, K=12 Virus can not affect most of agents, it disappears soon after threshold



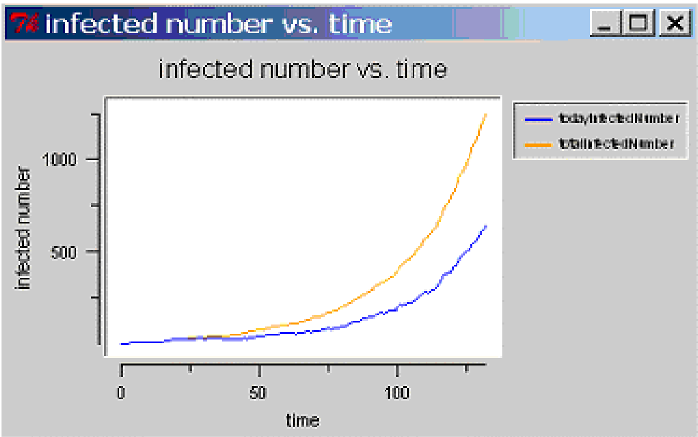
T=2, K=20 Virus spread until all agents are infected.

Two pictures above show that:

There is a K'. When K<K', virus disappear soon after threshold. When K>K', virus effect all nodes. (K' is nearly 16)



T=2, K=20 Virus spread.



T=3, K=20 Virus spread sooner in evidence

Two pictures above show that:

Transmission velocity of the virus is very sensitive to T

Four pictures above together indicate that:

T & K are the sensitive network parameters which related to the speed of transmission of the epidemic. If we want to control SARS, it is a good idea to make policies to reduce T and K, which means not only speeding up to find infective individual, but also noticing people to have fewer contacts to others then usual.

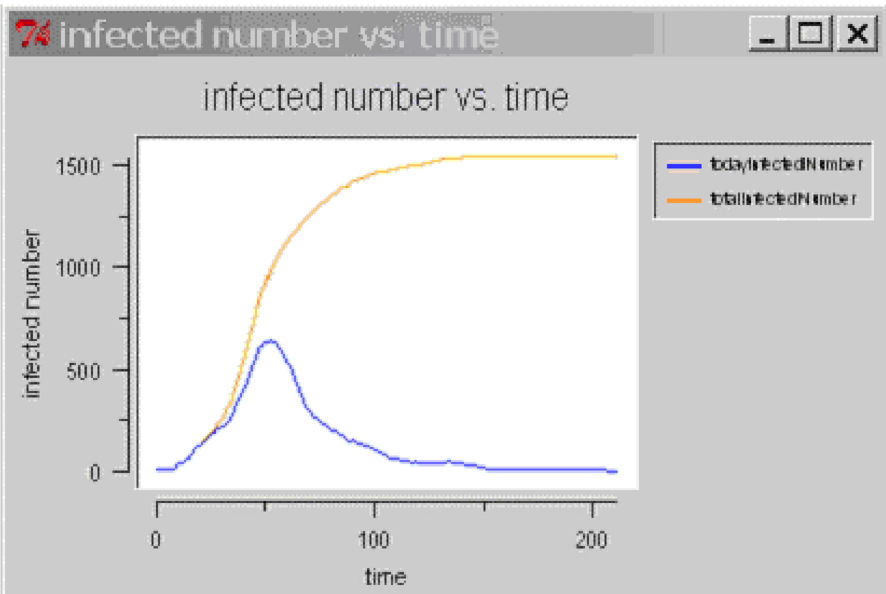
2.2 Self-insulated mechanism

Question:

Until now, results show self- attenuation or unlimited infection. Neither of them is accord with real circumstances. What do we need to control the serious trend after many agents get infected?

Mechanism :

When a agent find todayInfectedNumber persist increasing in last 3 step, it decrease its K by 2, until todayInfectedNumber stops increasing.



T=2, K=80 Even K=80>>K' (K' is nearly 16), fearful trend has been controlled

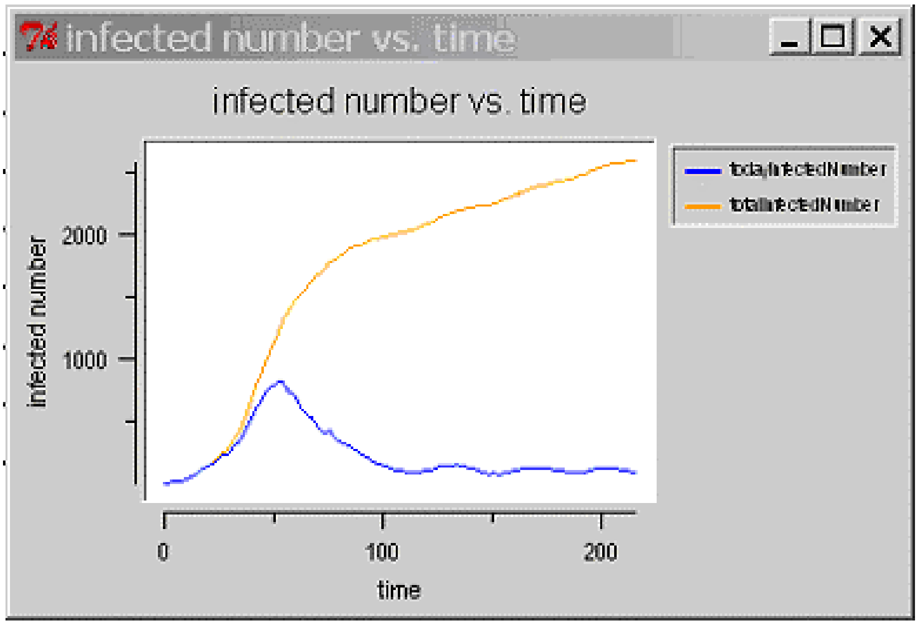
The picture shows that:

Self-insulated policy is efficient to control the spread of SARS.

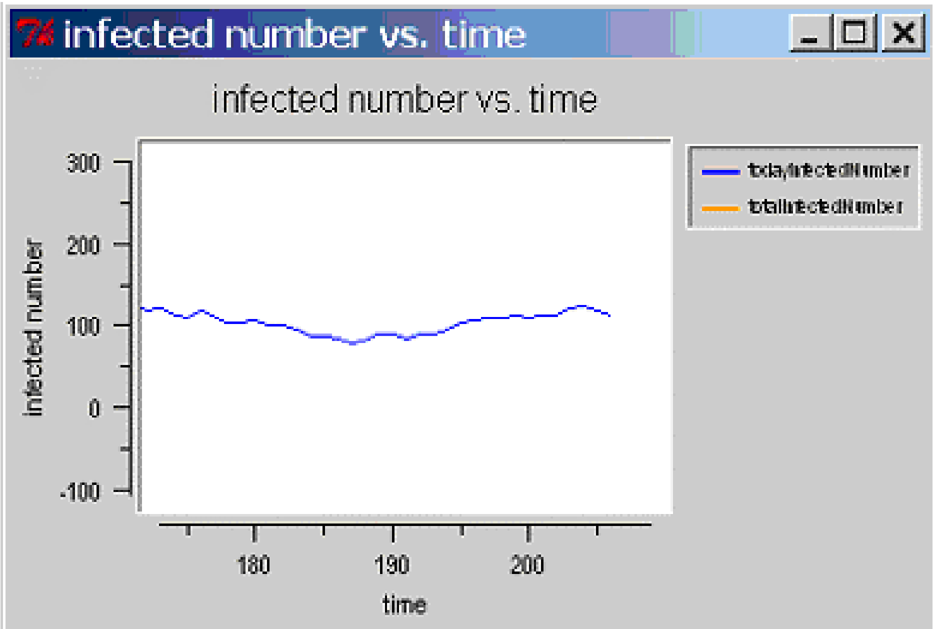
2.3 Alert-loosened mechanism

Question:
  When the epidemic situation is weakened, might people loosen alert against virus?

Mechanism:
  When agents find todayInfectedNumber keep decreasing for 3 steps and todayInfectedNumber is lower than 100, they add their K with 2 until todayInfectedNumber stops decreasing.



T=2, K=80 todayInfectedNumber can hardly reach 0, and totalInfectedNumber keep increasing.



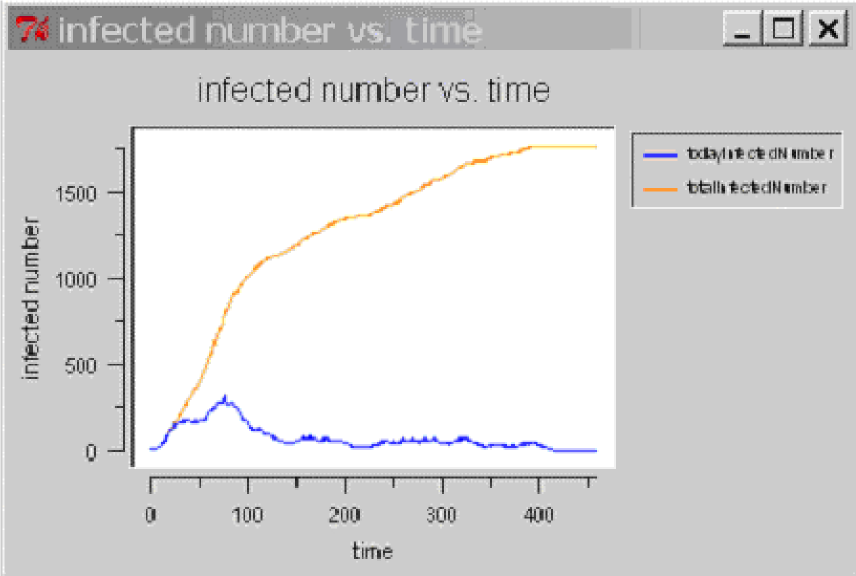
T=2, K=80 Tail of todayInfectedNumber, just around 100.

The two pictures above show that:
Even epidemic situation is weakened, people should not loosen alert. If they think things lightly, they virus can hardly be eliminated.

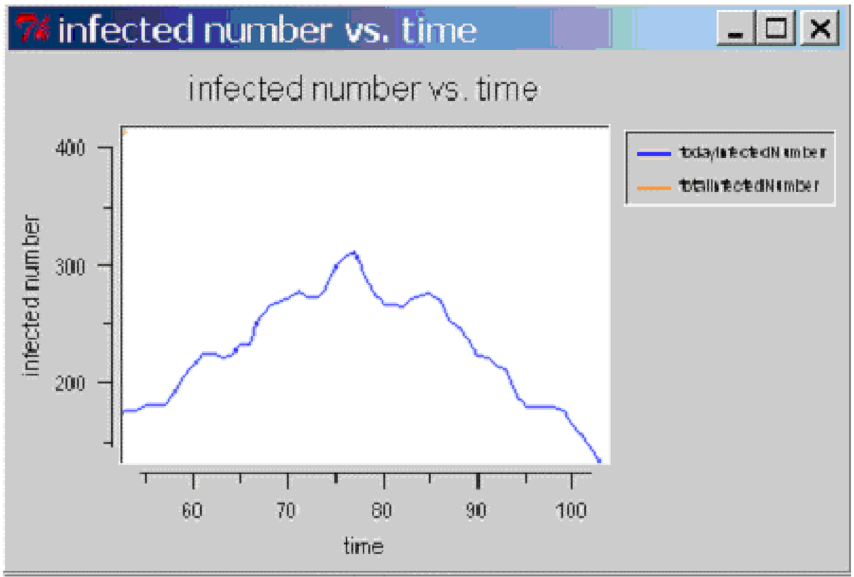
2.4 Information diaphaneity

Add a parameter:
infoDiaphaneity----How many agents in this model can get the epidemic situation in good season?

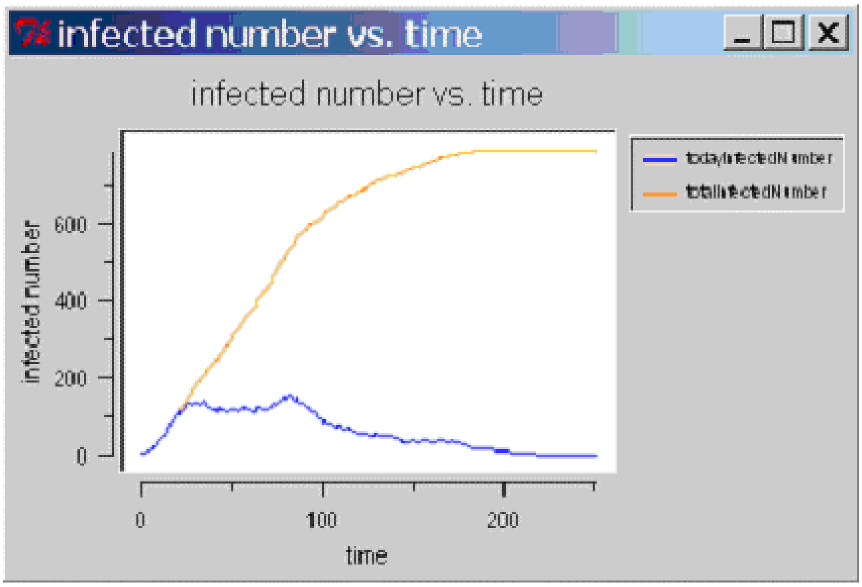
infoDiaphaneity represents the ability of public media to propagandize the epidemic situation so that people may insulate themselves in time.



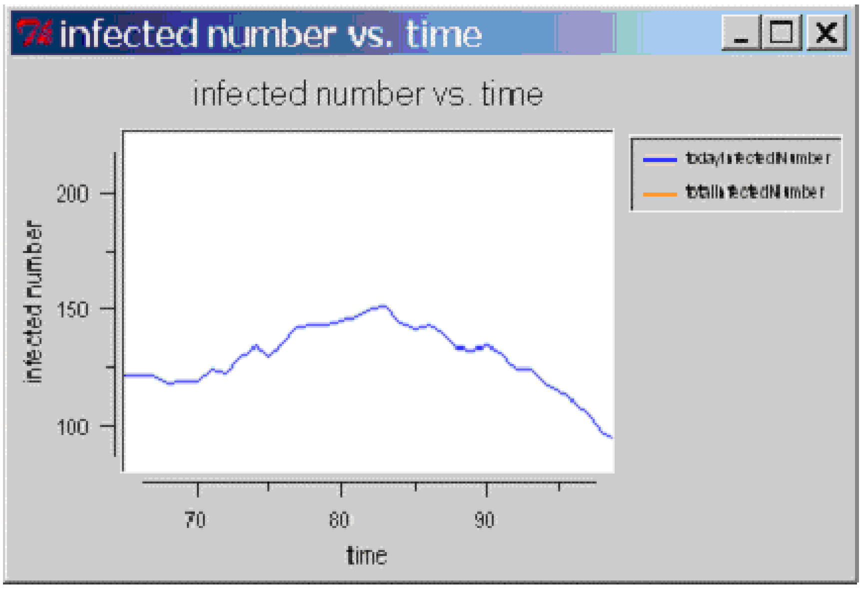
T=2, K=60 infoDiaphaneity=70%



Top area of todayInfectedNumber in the above picture, highest value is about 300.



T=2, K=60 infoDiaphaneity=100%



Tail of todayInfectedNubmer in the above picture, highest value is about 150.

Form the above four pictures we can find:

With high information diaphaneity, it takes more little time to eliminate the virus and the highest value of todayInfectedNunmbr is lower as well. That's to say, public media's drumbeating is of great importance to help to duel with the serious epidemic.

3. Conclusion

In the experiment, a small world model is introduced to fit the transmission properties of SARS. When the results successfully show the same diffuse trend as virus in real circumstance, the model is then used to find out the most critical network parameters relating to the speed of transmission of the epidemic.

Once we get the main factors (T & K) , we can implement feedback mechanisms to check if some measures the government carry out are efficient.
Such as:

1. Does Self-insulated policy work?
2. If people lose alert when the epidemic situation is weakened, what happen?

And, we can also study impact of some factor coming from outside of the system, like the Media. The only thing that needs to be changed is to add a global parameter(infoDiaphaneity).

References:

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2. *Volker Grimm, Eloy Revilla, Uta Berger, Florian Jeltsch,Wolf M. Mooij, Steven F. Railsback,Hans-Hermann Thulke, Jacob Weiner, Thorsten Wiegand, Donald L. DeAngelis, "Pattern-Oriented Modeling of Agent-Based Complex Systems: Lessons from Ecology", SCIENCE VOL 310 11 NOVEMBER 2005.*
3. *Chrisof Kochi and Gilles Laurenti, "Complexity and the Nervous System", 2 APRIL 1999 VOL 96 284 SCIENCE.*
4. *D. J. Watts and S. H. Strogatz, Nature 393, 440 (1998).*