Multi-agents Simulation on Unconventional Emergencies Evolution Mechanism in Public Health

Qing Yang* and Fan Yang
Management School, Wuhan University of Technology,
430070 Wuhan, P.R. China
yangq@whut.edu.cn

Abstract. Based on the cellular automaton principle and multi-agents theory of complex systems, this essay studied the public health unconventional emergencies generation and evolution mechanism, established evolution model and carried out simulation of the public health unconventional emergencies evolution mechanism, and finally took SARS emergency for an example. Research results showed that the evolution of the public health emergency often promotes other linkage emergencies, the damage of linkage system is larger than that of promotion system, and the damage is uncontrolled except for controlling the promotion system effectively, just like isolation measures or inject vaccine for individual of the promotion system so as to prevent promotion system from producing linkage hazards.

Keywords: Public Health Unconventional Emergencies, Evolution Mechanism, Cellular Automaton, Multi-Agents Simulation, Promotion System, Linkage System.

1 Introduction

H1N1 influenza, SARS and other emergencies (hereafter referred to as emergencies) put forward new requirements for the public health emergencies management. In order to conduct emergencies management scientifically and effectively, we should study and figure out the evolution mechanism of emergencies. According to the system theory, emergencies’ generation-evolution mechanism can be concluded as a kind of interaction among three basic elements composed of man, substance and environment [1], and its evolution process can be divided into five periods which includes incubation period, outbreak period, development period, recession period and death period [2].

In this essay, we take the advantage of the multi-Agents simulation technology as the development platform [3] and complex system critical theory [4] as the basis to construct the cellular automata model [5] of the evolution process. The model

* Author introduction: Qing Yang (1962-), doctor of management, professor, doctoral supervisor, research direction: crisis management complex system, venture capital and high technology industrialization, etc.; Fan Yang (1980-), doctoral candidate, research direction: crisis management complex system.
simulates the generation and evolution process of the emergencies, in order to observe how individuals lead to group phenomena and to analyze the simulation results of SARS.

2 Evolution Model

2.1 Evolution Mechanism

In the study of the causes of emergencies, scholars often regard superficial induction factors as the fundamental cause, and overlook the critical state and internal energy accumulation in a complex system when the stability of complex system undergoes damage. Emergency is a state which derivates from some kind of imbalance in complex system. The essential reason is that energy accumulates to a certain extent which throws the system in a critical state, an incentive to break the balance. Such critical state always occurs spontaneously in imbalanced system, called as the self-organized critical state. The critical state bridges the gap between the rules and disorder in concept, as a medium state. This state is not static, not lapsable casually but approximate to an extremely unstable balance, just like sand is always on the edge of the upheaval [6].

Public health emergencies inner mechanism coincides with that above indeed. The inner cause of its evolution is due to final explosion of virus infection caused by energy accumulation progress along with the diffusion of virus among people and this explosion without subsequent timely and proper control will lead to other explosions as to generate successive linkage explosions of emergencies. In this essay, the model is on the basis of secondary linkage emergencie which means an explosion of the public health emergency triggered another associated emergency.

2.2 Cellular Automata Mechanism

This essay applies cellular automata theory to construct the evolution model of public health emergency, while the cellular automata model is a kind of dynamic system in which time and space are discrete. The principle of the model is that every cell in limited discrete state scattered in Lattice Grid, following the same reaction rules, update synchronously according to a certain local rules. A large number of cells bring about the evolution of a dynamic system through simple interaction [7]. Different from general dynamics model, cellular automata is not strictly defined by physical equation or function, but composed by a structure of rules determined by a series of models.

2.3 Model Design

This essay constructs the model based on the linkage evolution mechanism and cellular automata above, of which there are two kinds of cells named A and B, constitute the independent subsystem respectively. The promotion system for A, while the linkage system for B, these two subsystems have the same grid space structure and the same size. There exists cells interaction between subsystems and two subsystems internal. Inside the subsystem, the interaction activities occur among
adjacent cells in coordinate frame, that is to say, one cell can interact with four adjacent cells. Interactions between subsystems could occur if the two cells, \( A_i \) and \( B_j \), at the same position but different coordinate grid space, \( A_i \) in explosion state will trigger \( B_j \) from stable state to latent state or explosion state. The evolution of the \( B_j \) is caused by \( A_i \) or by of the same kind adjacent \( B_j \).

Evolution control is implemented by the real-time control and pre-definition for state parameters of \( A_i \) and \( B_j \), respective internal transfer operators in A or B, and transfer operators of \( A_i \) to \( B_j \).

Refer to figure 1, it shows the demonstration of the evolution structure of \( A_i \) to \( B_j \), in which \( C_{ii} \) represent the unilateral interactions between them.

![Fig. 1. Cells interaction model](image)

### 3 Construction of Multi-agents Simulation Model

The model is one application of swarm2.2, a multi-agents platform. The concept of agent was proposed by American scholar-Minsky at the earliest, in Intelligence Society[8], which means one kind of entity have the abilities of self-adaptation and self-government, to recognize and simulate intelligent actions[9]. The format definition is below:

\[
\text{Agent:= \{ } S_m, A_g \text{\}} 
\]

\( S_m \) represents the internal state of Agent; \( A_g \) represents the function or external interaction[10].

This simulation model establishes promotion system A consisting of \( M \) cells, the linkage system B consisting of \( M_2 \) cells. Every cell is in its respective grid unit. The grid space of them have the same numbers of grids-M units \( (M=\text{world } X \times \text{world } Y, \text{world } X \text{ and world } Y \text{ both mean the verge of space}) \). But \( M_2 \) is less then \( M \), the number \( M_2 \) depends on the density \( \rho \) of B system. And \( \rho \) is an input value with range from 0 to 1. Each cell owns a coordinate position \( (x\text{Pos}, y\text{Pos}) \). After that, it can make cell \( A_i \) and \( B_j \) to transfer energy between them or in them, and to simulate the process of explosion of the emergency. Cells have three distinct states which consist of stable state, latent state and explosion state. The initial state of system A is except for one random cell in latent state, all the other cells in stable state. All cells of system B are in stable state and are dispersed in grid unit randomly.
The simulation process as shown in Figure 2:

![Simulation flow chart]

Fig. 2. Simulation flow chart

System operates $T$ cycles, each cycle advances step by step according to its transfer operator. $A_i$ cell’s state at $t+1$ step is decided by status parameter $X_{it}$ at $t$ step, adjacent total input $H_{it}$ at $t$ step, time increment parameter $\Delta t$ and evolving rule $F_i$ of cell $A_i$. Transfer evolution formula is:

$$X_{i(t+1)} = F_i(X_{it}, H_{it}, \Delta t)$$  \hspace{1cm} (1)

B system’s evolution contains $B_i$ cell’s internal action and the action of $A_i$ to $B_i$. The former transfer evolution formula is the same with formula (1). Latter evolution pattern is that a single $A_i$ evolves to the extent of explosion which may trigger $B_i$ to change state. If once $B_i$ is aroused to evolve, energy $E(A_i)$ of $A_i$ will be changed into zero, and this $B_i$ could be given some energy from it to change it’s state or to enhance its internal energy.

$B_i$ cell’s state at $t+1$ step is decided by status parameter $X_{2it}$ at $t$ step, adjacent total input $H_{it}$ at $t$ step, time increment parameter $\Delta t$ and evolving rule $F_{2i}$ of cell $B_i$. Transfer evolution formula is:

$$X_{2i(t+1)} = F_{2i}(X_{2it}, H_{2it}, \Delta t)$$  \hspace{1cm} (2)

4 Simulation Analysis of SARS Case

Combined with the characteristics of SARS, the simulation makes energy transfer from system A to B or in the internal of them to simulate the process of SARS explosion. System A represents SARS itself and the system B represents medical scare emergency triggered by SARS.

The results of simulation test are graphs for three observation measured respectively by latent value as the cells in the latent state in current cycle, the explosion value as total amount of cells in explosion state in current cycle and total destructive value, which means the accumulation of energy in current cycle. Moreover, two curves respectively signify each situation of system of A and B in observation graph.

Known from SARS, it's linkage emergency has a higher density in space. Because its impact is considerable wide range, the initial influence degree is high as well, the linkage system performs weak defensive ability, even nothing at all, while the transfer action of SARS self to linkage system is so strong and linkage system evolution ability is strong too, so, input value of density $\rho$ of B space is set to 0.8, the defensive
ability $z$ of B against A is equal to 0.1, the rate $c$ of action transfer from A to B is set to 0.8 and B’s gene length parameter $L_{(B)}$ is set to 25. The result of simulation as shown in figure 3:

![Graph showing the results of SARS linkage evolution simulation](image)

Fig. 3. Results of SARS linkage evolution simulation

In figure 3, the latent value figure shows that latent value of SARS is over that of linkage system before 42 cycle and maximum of both can reach higher, while SARS reach max 225, a comparative higher amount which indicates that late harm is more serious. Seen from explosion value, linkage system explode slightly later in curve than SARS and restrained by model, the space density of linkage system is limited to comparative higher 0.8, lower than the density of SARS system (equal to 1). Therefore, the explosion value of linkage has been below the SARS system. However, if the situation reversed, linkage system will show more power of explosion. Destruction power graph clearly shows the destructive force of the two systems, the linkage system is obviously more harmful than that from SARS system itself.

The results of simulation approach to real world, that is to say the model can reflect the destruction of SARS and linkage destruction from SARS. The linkage destruction would lead to a larger damage without timely and proper control.

## 5 Conclusion

The evolution of the public health emergency often promotes other linkage emergencies, which explode more swiftly and follow at their motivation systems heel. Furthermore, higher destructive power will be brought up since the complexity of situation, high density and weak defensive ability of linkage systems. Therefore, in order to control the linkage destruction effectively, we must carry out effective and swift isolation measures or inject vaccine for individual of the promotion system so as to prevent promotion system from producing linkage hazards.

**Acknowledgments.** This research is supported by National Natural Science Foundation of China (Grant No. 91024020).
References

1. Ma, Y., Wang, C.: Analysis of the Causes of Important Sporadic Events. Journal of Wuhan University of Technology (Information & Management Engineering) (9), 92–95 (2006)
2. Fink, S.: Crisis Management: Planning for the Inevitable. Universe, Inc., Lincoln (2002)
3. Chai, X., Jin, X.: The 3D Simulation Modeling and Application of Paroxysmal Calamity in Public Places Based on Agent. Journal of Shanghai Jiaotong University (10), 1669–1674 (2008)
4. Li, M., Zhang, K., Yue, X.: Study on emergency complexity theory. China University of Politics and Law of Finance (6), 23–265 (2005)
5. Xuan, H., Zhang, F.: Simulation and application of complex system. Tsinghua university press, Beijing (2008)
6. Buchanan, M.: Ubiquity: The Science of History. Crown Publishers (2001)
7. Ji, H., Wang, X.: System Modeling and Simulation. Tsinghua university press, Beijing (2004)
8. Minsky, M.L.: Society of Mind. Touchstone Press (1988)
9. Yang, Q., Shi, Y., Wang, Z.: Multi-Agent Research on Immunology-based Emergency Preplan. In: Proceedings of 2010 International Conference on e-Education, e-Business, e-Management and e-Learning (IC4E 2010), pp. 407–410. IEEE Computer Society (2010)
10. Khalil, K.M., et al.: Multi-Agent Crisis Response Systems - Design Requirements and Analysis of Current Systems. Working Paper (2009)