Modeling and Simulation for the Spread of H1N1 Influenza in School Using Artificial Societies

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Abstract. According to the outbreak of H1N1 influenza on campus in Langfang city, Hebei province, at north of China in 2009, this paper constructed an artificial society model of the school, and simulated the spread of H1N1 influenza at the fifth floor in dormitory building. Firstly, it built the geographic environment model in accordance with the real dormitory building and a social relationship network model, including classmates, roommates and playmates. Secondly, it designed the behaviors and activities of students during a day, and built role based agent models of student. Each agent student had three roles, which were susceptible, infectious and recovered student. Finally, it conducted simulation experiments to compare the emergency measures of segregating non-classmates and segregating non-roommates.

Keywords: Public Health Security; Modeling and Simulation; H1N1 Influenza; Emergency Management.

1   Introduction

Public health security is closely related to national economy and social stability. So the sudden outbreak of epidemic will cause serious harm to the health of people, and damage national economic development. For example, the outbreak of SARS [16] in 2003 and H1N1 influenza [1] in 2009 has seriously affected the lives of people and economic development, and even led to the death of some patients. Therefore, it is an urgent issue that how to manage the sudden outbreak of epidemic effectively and fleetly. Owing to the fact that the outbreak of epidemic is always sudden and unpredictable, it is required to make reasonable and effective emergency management strategies beforehand. So the traditional research mode of emergency management, "forecast-response", cannot meet the demand. However the research mode based on modeling and simulation [2], [3], "scenario-response [4]", has become an important way to resolve sudden outbreak of epidemic.

The spread of epidemic is complex and variable that has many related causes [5]. So the traditional simulation aiming at approximating the single reality cannot simulate the complex and variable scene of epidemic emergencies. Whereas artificial

societies [6], [7] based modeling and simulation, as a bottom-up approach, could come forth complex social phenomena through evolution, interaction and cooperation between multi-agents. So it is an effectual resolution for emergency drills, emergency mental training and assessment of emergency strategies to research epidemic emergencies management.

In the spread of epidemic, the school is very special high-risk places. Because in school, students are high concentrated, and keep high consistency in behaviors and frequently close contact, such as living, learning, eating, playing and so on, it results in that the school is vulnerable to the outbreak of epidemic [8], [9], [10]. For instance, in the spread of H1N1 pandemic influenza in Beijing in 2009, more than 70% of outbreaks took place in schools. So protecting students from epidemic is an important task in public health emergency management.

This paper constructed an artificial society to simulate the spread of H1N1 influenza at the fifth floor in dormitory building according to the outbreak of H1N1 influenza on campus [11] in langfang city, Hebei province, at north of China in 2009. It made the foundation for simulating the spread of H1N1 influenza in any school and decision making for epidemic emergencies.

The remainder of this paper is organized as follows. Section 2 built the geographic environment model of the fifth floor, social relationship network model among students, behaviors and activities model of students during a day, and role models of students. Section 3 conducted simulation experiments for different measures of segregation, and compared these results of experiments.

2   Modeling with Artificial Societies

2.1   Geographic Environment Model

According to the real structure of the fifth floor and the population distribution of students in dormitory building, geographic environment model is built as figure 1. There are three classes in the fifth floor, including Class 4, Class 7 and Class 13, and 64 dorms, 3 WC, 3 washrooms, 3 storages, 3 Classrooms, 1 balcony. There are 8 dorms belong to Class 4, whose names are the odd number from 501 to 505 and the even number from 502 to 510, and 25 dorms belong to Class 7, whose names are the odd number from 507 to 525 and even number from 512 to 540, and 21 dorms belong to Class 13, whose names are the odd number from 527 to 543 and the even number from 542 to 564. And there are 6 students live in each dorm.

2.2   Social Relationship Network Model

The spread of H1N1 influenza is propelled by close contacts among students. And the probability and intensity of close contacts among students are depended on the mutual social relations [12], [13]. For instance, the probability and intensity of close contacts among roommates is higher than the one among non-roommates, and the same as classmates and non-classmates. In this paper it researched three relations between students to build social relationship network model. These relations are classmates,

roommates and playmates. Classmates could be roommates and non-roommates, but non-classmates must be non-roommates. And playmates could be classmates and non-classmates, as well as be roommates and non-roommates. The closeness of relations among students is different and their proportions are shown in table 1. In simulation experiment, these proportions determine the probability distribution of contact objects.
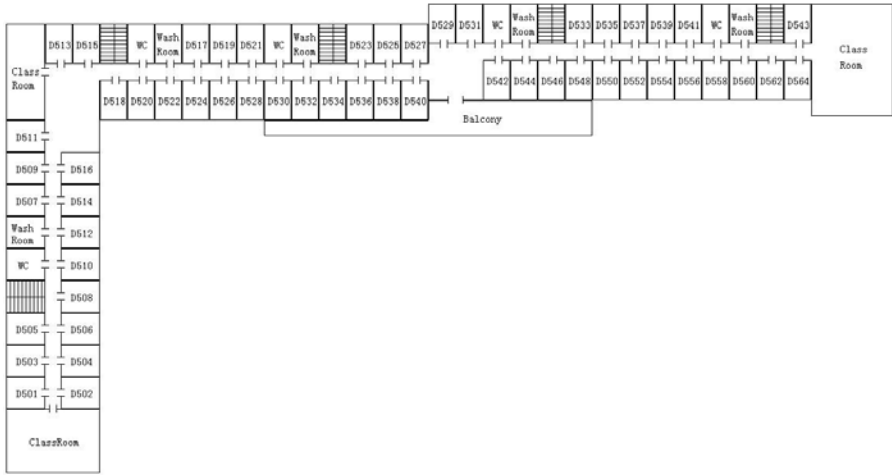

Fig. 1. The fifth floor model

Table 1. Closeness of relations between students

	Classmates		Non-classmates
	Roommates	Non-roommates	
Playmates	40%	20%	10%
Non-playmates	20%	10%	0%

The relations of classmates and roommates are confirmed by dorms which students live in. If students live in the same one dorm, they are roommates and classmates. If students live in different dorms, they are non-roommates, and they are classmates when these dorms belong to the same one class, or they are non-classmates. The relation of playmates is not confined to living place. In simulation experiments, it assumed that each student has 0 to 5 playmates, which are randomly generated at the beginning of experiment. Figure 2 shows random relationship among playmates.

In the evolution of artificial societies, relationships among agents may change continually [14]. It makes the configuration of artificial societies variable so as to come forth complex and diverse social phenomena. In this social relationship network model, the relations of classmates and roommates are unchangeable. However playmates may change with the evolution of artificial societies. In simulation experiment students who contact continually in certain time may become playmates. Contrarily,
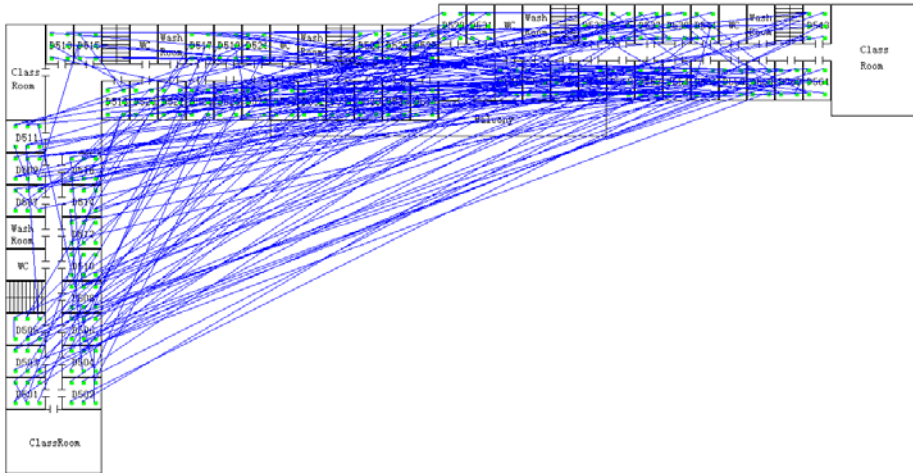
Fig. 2. Contact relationships among playmates

Table 2. Behaviours and activities model

Time	Location	Contact probability	Time	Location	Contact probability
7:00-8:00	dorm, washroom, WC	60%	12:00-13:30	dorm, balcony, WC	75%
8:00-8:50	classroom	10%	13:30-14:30	dorm, WC	6%
8:50-9:00	classroom, dorm, balcony, WC	80%	14:30-15:20	classroom	10%
9:00-9:50	classroom	10%	15:20-15:30	classroom, dorm, balcony, WC	80%
9:50-10:10	classroom, dorm, balcony, WC	80%	15:30-16:20	classroom	10%
10:10-11:00	classroom	10%	16:20-22:00	classroom, dorm, balcony, WC	75%
11:00-11:10	classroom, dorm, balcony, WC	80%	22:00-23:00	dorm, washroom, WC	60%
11:10-12:00	classroom	10%	23:00-7:00	dorm, WC	2%

students may become non-playmates when they have not contacted with each other for a long time.

2.3 Behaviors and Activities Model

The Spread of H1N1 influenza is closely related to the daily behaviors and activities of students. The main behavior which directly causes the spread of H1N1 influenza is close contacts among students. In daily life of students, the spread occurs with diverse probabilities of different behaviors and activities, and students have various behaviors

and activities during a day. In this paper, it designed the following behaviors and activities, including getting up, washing, going to toilet, going to classroom, taking classes, playing in dorms, playing in balcony, going to bed, talking, and learning in classroom. It defined behaviors and activities model during a day as table 2. As shown in table 2, it determines different action location in each time phase during a day, and contact probability derived from empirical data. In simulation experiment, according to the contact probability, agent decides whether have close contact with other agents in each simulation step, such as playing, talking, etc.

2.4 Role Models

In order to achieve that attributes and behaviors in agent model could dynamically change, we builds various role models for the same one agent [15]. During the evolution process of artificial societies, when the states of agent satisfy role changing conditions, the value of attributes and parameters of behaviors transfer from one role model to another role model. So it realizes role evolution of agents. In this paper, we build three roles, such as susceptible, infectious, and recovered student, which are shown in figure 3. As seen from figure 3, the green square represents susceptible student who has never been infected by H1N1; the red circle represents student infected by H1N1 influenza; the blue hollow box represents recovered student who has ever been infected by H1N1 and have antibody to H1N1 influenza.
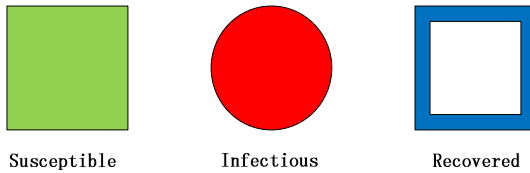

Fig. 3. Role models

   Three role models have different attributes and behaviors. The infectious role model has special attributes of epidemic type and infected time, and the behavior of infecting other students. However, the recovered role model has special attribute of antibody type and the behavior of preventing from H1N1 influenza.

3 Simulation Experiments

With these models above, we could design and conduct simulation experiments. In simulation experiments, we set the walking speed of each agent to be one meters per second, and set simulation step to be one second. And the beginning time is at 7 am when students are getting up, and the whole simulation time is 30 days. Moreover, we assume that there is one infectious student in class 4 at the beginning of experiments, and it takes emergency measures for the outbreak of H1N1 influenza when the school

detects more than 10 students infected by H1N1 influenza. The emergency measures include segregating non-classmates and segregating non-roommates.

We conduct three simulation experiments, experiment (a), experiment (b) and experiment (c), to compare different measures for preventing student from H1N1 influenza. In experiment (a), no measures are taken. In experiment (b), students are segregated from non-classmates when the school detects more than ten students infectious by H1N1 already. In experiment (c), students are segregated from non-roommates. They have been confided to their dorms, and not allowed to go to class-room, balcony and other dorms. Figure 4 is a scene of running simulation experiment (a) at time from 16:20 to 22:00.
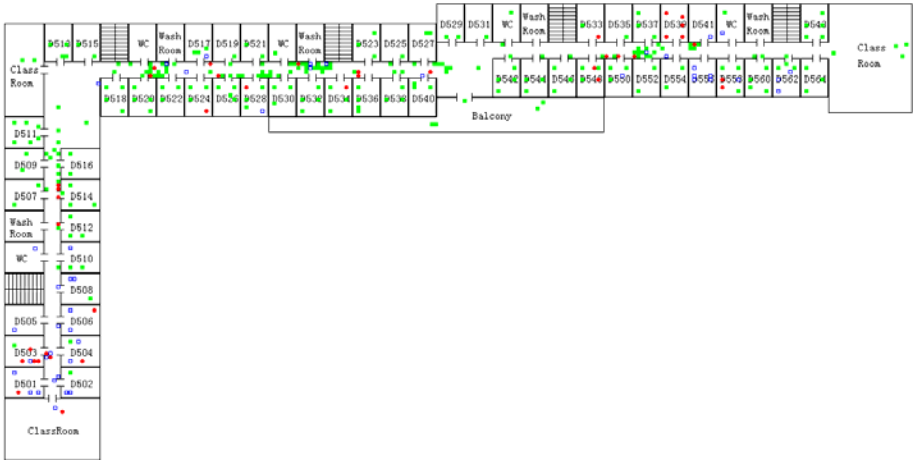

Fig. 4. Simulation experiment scene

The results of these experiments are respectively shown in figure 5 (a), (b) and (c). Each experiment has 4 graphs for class 4, class 7, class 13 and the fifth floor, to depict the changes of the number of susceptible, infectious and recovered students with three different kinds of curves.

As figure 5 (a) shown, the only one infectious student in class 4 at the beginning of experiment, has spread H1N1 virus abroad to class 7 and class 13. And we can see from figure 5 (b) (2) that no students are infected by H1N1 influenza in class 7. It proves that emergency measure of segregating non-classmates has prevented class 7 from infectious students. From figure 5 (a) (4), (b) (4), and (c) (4), we know that the number of infectious students in the fifth floor decline, and become zero more and more quickly. It could conclude that the emergency measures of segregating non-classmates and non-roommates could effectively protect students from the spread of H1N1 influenza, and that segregating non-roommates is a much better measure than segregating non-classmates.
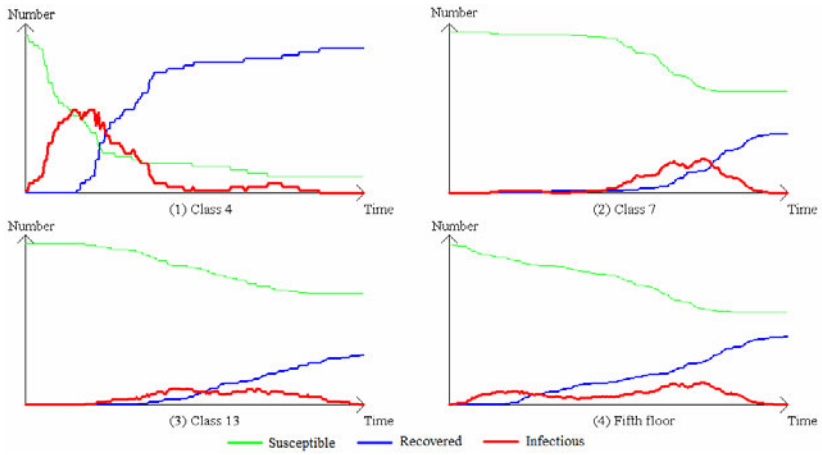
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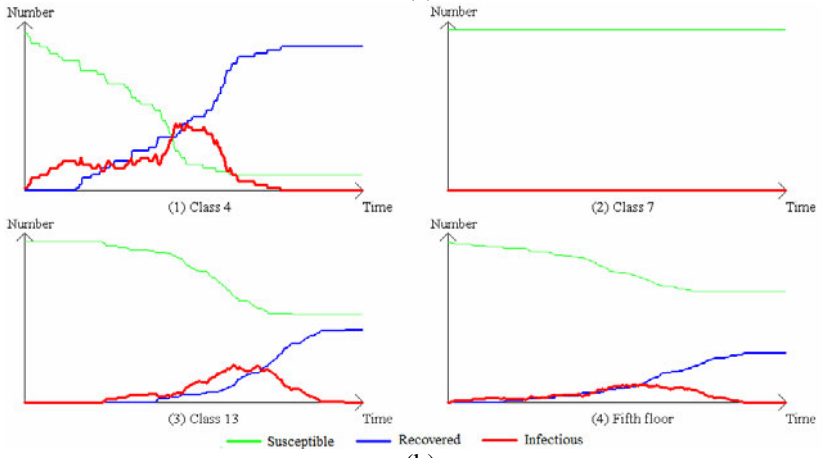
(b)
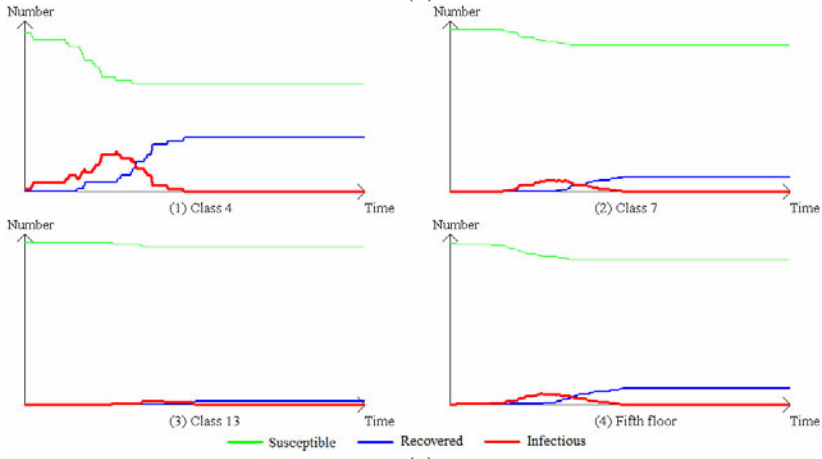
(c)

Fig. 5. Student number curves in three roles

4   Summary and Outlook

According the case of the outbreak of H1N1 influenza on campus in langfang city, this paper built models of the fifth floor and behaviors of students in the school. It simulated the spread of H1N1 influenza and reproduced the scene of the outbreak of H1N1 influenza. Besides, it designed a variety of random parameters in simulation experiments, and two kinds of segregation strategies, and analyzed the results of experiments with different segregation strategies. In the following works, we will build a whole school model using artificial societies on the basis of what we get from this paper to simulate the outbreak and spread of epidemic in school, and to support decision making in emergency management.

Acknowledgments

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