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Systems Engineering Procedia 2 (2011) 23 – 32

Procedia
Systems Engineering

Engineering Modeling Unconventional Emergency Artificial Society

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Abstract

Lots of engineering modeling methods have been designed to investigate and analyze complex systems, such as artificial life, cellular automata and artificial society. Artificial society is a bottom-up modeling method which is a new paradigm of simulating human society from bottom up. A great amount of work has used the artificial society method. However, how to engineering modeling artificial society with unconventional emergency is still worth to research. In this paper, we take into account the particularity of unconventional emergency management to research artificial society modeling with the viewpoint of software engineering. Then, we propose an unconventional emergency management-oriented artificial society model, including agent model, environment agent model and emergency model. Furthermore, agents in the artificial society adopt the self-adaptive approach —binding mechanism, including role binding and emergency model binding. Then, the proposed model is illustrated by an example of H1N1.

Keyword: unconventional emergency; artificial society; agent; role; group; binding mechanism; engineering modeling

1. Introduce

As the rapid development of transportation, telecommunications and other industries have brought many benefits to people's lives and social development, dissemination of information has became faster, interactions among people have became more and more frequent, interactive areas are becoming more and more widely, and so forth. At the beginning of this paper, let us look at a set of data about China:

- In China, the total length of transportation was about 1.245 million km in 1980, and in 2006 approximately reached 5.8187 million km, that increased 2.44-fold. Especially, in recent years China high-speed railway is developing rapidly. Currently, high-speed railway operation mileage of China is longest in the world, and the speed of China high-speed railway is also fastest in the world;
- At the same time, the quantity of mobile phone users of China is more than 900 million, and China has become the country with the largest mobile phone users in the world.

It also has brought some bad aspects: the speed and the scale of emergencies spreading in the society are increasing, the frequency of occurrence of emergencies is also rising, and the local conventional emergencies may evolve into large-scale unconventional emergencies. For example, H1N1 was outbreak in Mexico in 2009.

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doi:10.1016/j.sepro.2011.10.004

Moreover, it continued to spread around the world, and eventually led to global impact.

Unconventional emergency is an emergency that has not adequate precursor, with significant features of the complexity, potential hazards of secondary derivatives and the devastating, and is difficult to be dealt with the conventional management approaches [1]. And unconventional emergency is the challenge and priority of the current research of emergency management. In order to study the evolution and development of unconventional emergencies in the society, researchers usually use some new methods, such as artificial life, cellular automata, artificial society and so on [2]. In this paper, we focus on artificial society. The idea of artificial society method proceeds as follow: firstly, through establishing the individual reality model (agent) in the society, agents must run to comply with some rules in the system; Then, emergencies bring effect on the artificial society, and we observe the emergence of agents' behavior and properties in macro-scale to study the evolution of emergencies and the appropriate emergency management. Therefore, the large-scale (tens of millions of agents) artificial society modeling is one of the key technology in the domain of emergency management.

Artificial society establishes the complex virtual society which is similar to the complex real society with multi-agents technology. In the recent, there are some multi-agent modeling and simulation platforms, including Swarm(Santa Fe Institute), Repast(North and Macal), MASON(GMU) and Anylogic(XJTechnology) [8][9]which are used for building large-scale multi-agent systems. Besides agents model, artificial society should establish the social relations model. However, Swarm and MASON can't specify the social network of agents, and the model of Repast and Anylogic is java model (so the work efficiency is limited). We make use of the idea of Model Drive Architecture (MDA), and establish the artificial society model (agents, environment agents, social relations and so forth) by graphical approach. Then, use the toolkit to transform the artificial society model to simulation model. Lastly, experimenters deploy simulation models on the computing servers to experiment. For this, we propose an artificial society model to build the artificial societies. In this paper, we introduce some knowledge of emergency management and artificial society. And we aim at studying artificial society engineering modeling. Then, we propose the artificial society model, including the formation of model elements, binding mechanisms and so forth.

2. Introduction of emergency management and artificial society

In order to solve the problem of complex social systems and the complexity of urban transport system, in 2004 [3]firstly proposed the social computing approach which consist of artificial societies for modeling, Computations experiments for analysis, Computations experiments for analysis and Parallel execution for control, referred as ACP. It is a new idea to solve issues of complex systems engineering modeling, analysis, calculation, control and management, mainly including three steps. Firstly, establish the corresponding virtual complex system with the method of artificial society engineering modeling. Then, design the computational experiments plan on the basis of artificial society model with the method of computational experiments. Lastly, synchronously deduce the virtual system and the physical system of the complex system, complementing each other, and manage the macro-scale behaviours between them. Estimate the status of the evolution of the virtual system to adjust management mechanisms and control methods in actual system. Thus, the study of artificial society engineering modeling is very necessary, as it's the foundation of the ACP method.

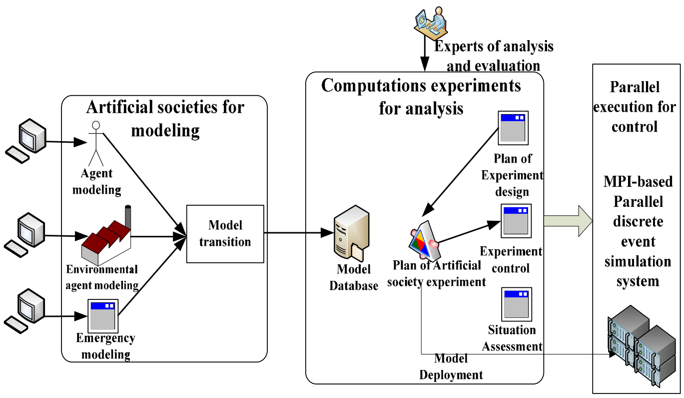

Fig1. ACP schematic diagram

2.1. Artificial society

Artificial society [4] [5] is a cross-discipline which combines sociology, computer science, MAS technology, systems science and some other areas. It's a bottom-up modeling method, by creating the individual model in the micro-scale and observing the emergence of behavior and attributes of the overall in macro scale. It may generate from the nonlinear interactions between Agents. Artificial society is a general method for complex systems, including multi-Agent technology, psychological aspect and complex social networks, and is used for simulating the real societies or economic problems

- Artificial society was initially used in economics, simulating some nonlinear economic phenomena such as stock of non-linear Aurora. Nigel Gilbert and Rosaria Conte edited and published "Artificial Societies — The Computer Simulation of Social Life" in 1955, marking the artificial society as an independent new discipline, and the study of artificial society was also carried out quickly.
- In 1996, Epstein and Axtel edited and published "Growing Artificial Societies - Social Science from the Bottom up", constructing a classical model of artificial society – Sugarscape [6]. It's a general model which is widely applied to areas such as social sciences and economics. Two types of entities have been defined, environment and agent. Environment is an area including a lot of resources, distributed according to some topology. Agent will consume its resources to survive. Agent is the person in artificial society, and each Agent has its own internal state and behavior rules. Agent needs to consume resources to survive, which should be searched in the environment by Agent. According to the requirement of the research, the behavior of Agent will be changed by changing environment regulations and rules. At the same time, explanation of some phenomenon or some new conclusions will be obtained by observing emergence of behavior and properties of the artificial society with simulation.

Unconventional emergency management-oriented artificial society model needs to create a city-scale artificial society, including the environment agents, agents and so on. For its specificity, the behaviour, properties and rules of a single agent must be as simple as possible, and it needs to be able to dynamically load emergency models during the run-time to do emergency experiments.

2.2. Emergency Management

Emergency management is born out along with the emergencies. In the process of emergency prevention, incident response and management disposal, government and public sector organizations take a series of response and management control measures to safeguard social stability and reduce the impact of emergencies. Emergency management involves prevention and emergency preparedness, detection and early warning, emergency response and rescue, and the subsequent recovery and reconstruction, that is the process of Forecast - Warning - Response – Recovery. For unconventional emergency management needs to respond to natural disasters, accidents, disasters, public health and other public emergencies that are with properties of sudden, evolution, extensive impact and so forth.

Unconventional emergency management is the emergency management that takes into account unconventional emergencies with significant features of the complexity, potential hazards of secondary derivatives, complexity, so unconventional emergency management needs to have a predictive capability, early warning capability, which requires artificial society model to describe real society accurately, and can well describe the social development under the influence of unconventional emergencies.

2.3. A sample of unconventional emergency

Unconventional emergencies have significant features of the complexity, potential hazards of secondary derivatives, complexity and so forth. We can understand "what is unconventional emergency" with a case. March 2009, H1N1 was outbreak in Mexico, and soon spread rapidly to more than 200 countries in the world. More than tens of millions of people were infected, and it caused over 10,000 deaths and serious consequences. In the short period of H1N1 outbreaks, H1N1 virus spread rapidly in the population, especially in schools, communities and other areas with dense population. So we can see the event is an unconventional emergency, with the characteristics of suddenness, no foreboding, complexity and affecting widely.

3. Artificial society model

Artificial society model needs to establish the agent population, and needs some statistics to describe the population agent as a whole, so we need a statistical model. We can use groups to characterize the social relations and collective psychology of agents. To support multi-resolution model and simulation, we need environment agent models. At the same time, in order to describe the emergencies, we need emergency models. Thus, artificial society model of unconventional emergencies management-oriented contains Agent model, environment agent model and emergency model, shown in Fig2. Compared to the general Multi-Agent System (MAS), the number of Agent in this model is enormous (city-scale artificial society). Therefore, agents' behaviour and rules need to be as simple as possible.

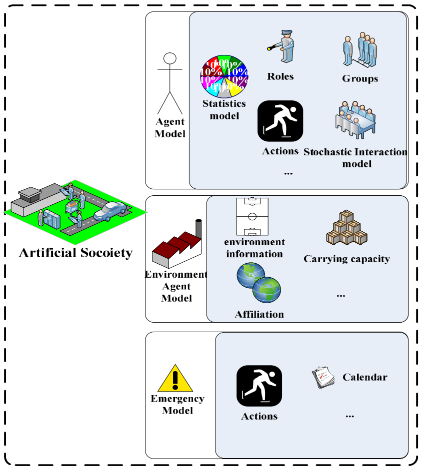

Fig2. Artificial society model schematic diagram

3.1. Agent model

Agent Model is the model that is needed to construct agents. It's the basis of artificial society model, constituted by statistical model, role set, action set, group and stochastic interaction model.

3.1.1 Statistical model

Statistical model describes the statistical properties of agents population in artificial society, such as total population (Total number of agents), sex ratio, age distribution and so on, describing the agents population overall.

The total number of agents describes the population size of artificial society to be constructed. The role ratio describes the proportion of various roles in the artificial societies. Role is mainly used to describe employment, function and behavior of agents in the artificial society. It's the identity of agents in the artificial society. Sex ratio denotes the sex ratio of agents in the artificial society. And age distribution table can count different ages or specific ages as needed, describing the proportion of different ages of agents.

These basic models simply describe the composition of agents in the artificial society.

3.1.2 Action set

Just like human in real society, agent has his own behavior in artificial society. Action set defines the actions of all agents, such as work, move and so forth. Action ID is the identity to distinguish different actions. The prerequisite constrains the action execution, which is the condition that must be met before the action execution.

Execution process defines the specific content of the action. Execution results show the state of agent after execution or the state of other elements to be changed. Agent description is the description of the behavior, which can be described in natural language or other forms.

3.1.3 Role set

Role set defines the categories of roles in the artificial society. Role ID is the identity to distinguish each role. Role name is the name of the role which specifies the occupation or function of an agent. A set of attributes will be used to describe the properties of the different roles. For example, for the student role, there may be properties named colleges, departments, grades and so forth. However, for a teacher role, there may be properties named college, department, subject and so on. Roles can also be divided in different granularities based on the need of simulation. For example, according to different grades, the student role can be divided into freshman role, sophomore student role and so on. All these will be considered while modeling. Schedule defines a regular trip of the role, which shows the possible actions of the role in each time period. In a period of time, a role may own multiple choices of actions.

3.1.4 Group model

There are many differences between artificial society and the general Multi-Agent system (MAS), and one of them is that in the artificial society agents own their social relations. Group model is used to describe a kind of social relations between different agents, such as the dormitory relations, etc. Member table of the group describes the group members. When the group composition relates to roles such as the relationship between teachers and students, the model need to give out the related roles and the scale of the related roles. When the group composition does not relate to roles such as friendship, the model will only give out the member size or scale. As the description of the structure and organization of social relations of agents in the artificial society, the group will have the frequency of activities, and in the group agents will have collective activities schedule together. And the activities schedule will be described with time and activities. Interaction between agents will exist in the group. However, not all of agents will interact with other agents in the group, and not every minute all agents will take part in the group. Thus, the size or scale of the members to participate the group interaction is given by the scale of the interaction. When taking part in group, the interaction probability is used to describe the possibility of agent interaction. For some special groups, such as unconventional emergency committee, some group decision will be made for the development of the emergency situation, thus affecting the development of the emergency in the artificial society. At the same time, to describe the artificial society group psychology, such as the group psychology in public safety incident, the group psychology could be specified by the group's action sequences, which will show the behavior of the group. For example, in Xinjiang "7.5" incident, insurgents constituted a group to the produce violence psychology through discussions, thus effecting on the society stability.

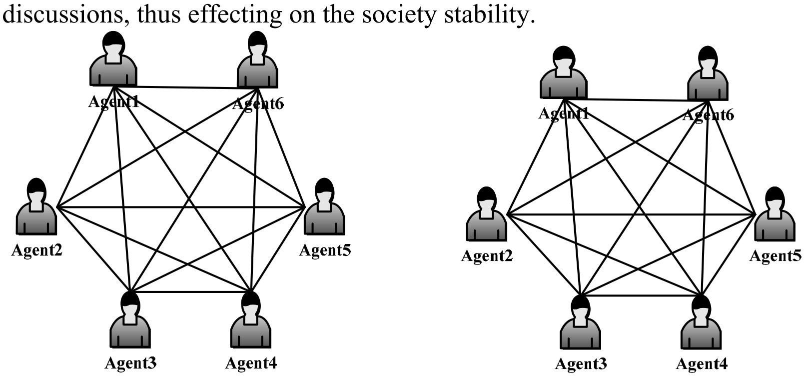

Fig3. (a)Group model; (b) Dormitory relation—social relation

3.1.5 Stochastic interaction model

The stochastic interaction model is used to describe the interaction between agents which happens outside the groups. This interaction may be contact with the space and events, such as the spread of virus, or the interaction between the two agents with social connection in some space. These interactions are stochastic, so we use the probability of the stochastic interaction to describe the possibility of the interaction between agents.

3.2. Environment agent model

Environment agent model is mainly to describe some environment entity, such as classroom and library. The environment agent model has its own function and actions, such as that it can either calculate the density of population, or provide resource to the agent. The environment agent model is a necessary part of the artificial society. Environment agent has a geographical scope, described by the height and the environment agent boundary point set about longitude and latitude. The environment agent's resources is limited, therefore the environment agent has a upper limit of population. Environment agent has his own activities, such as the library opens from 8:00am to 10:00pm. There is a affiliation between environment agents. For example, a didactical building has 50 classrooms, classrooms belong to the didactical building, and didactical building contains an environment agent set (50 classrooms). With the dynamic evolution of the artificial society, agents' activities are also dynamically changing in the environment, and the environment agent records all active agents in the current environment with the population agents set. So the environment agent can easily calculate the population density, spread of the disease, etc. Driving by the unconventional emergency, environment agents will have some emergence behavior in the artificial society. For example, calculation emergence, population emergence (agents may gather in the environment agent), etc.

3.3. Emergency model

Facing the artificial society model of the unconventional emergency management, emergency model is an important component of artificial society model. Emergency will affect different agents' behaviour, so different emergencies will produce different behaviour. We use the emergency action set to describe the actions triggered by the emergency, such as the H1N1 virus model can cause the action—"self-test temperature". In artificial society, for different roles the emergency effect is different. Emergencies mainly affect the agent's activities schedule: hang agent's role activity schedule and make the emergency activities schedule as the agent activities schedule. Emergencies conducing to changes of activities schedule is taking into account different roles, and the impact is likely to be the same, so we use the role set to record these kinds of roles(with the same impact).

3.4. Self-adaptive mechanism – binding mechanism

Agents need some self-adaptive methods and mechanisms. We use the self-adaptive mechanism - binding mechanism in artificial model, including role binding [7] and emergency model binding mechanism. Role binding is mainly used to simplify the functions, and agents' behavior, properties and activities schedule related to roles should be located in roles. If an agent plays a role, it will obtain all the properties, behavior and activities schedule of the role at the same time. And agents can exit or enter a role to adapt to environmental change by dynamic role binding. Emergency binding is mainly in response to emergencies, similar to the role binding, and agents will obtain properties, actions and activities schedule of the emergency model. Then, the activities schedule of roles played by the agent will be suspended to adapt to the impact of emergencies.

3.4.1 Role binding mechanism

Role is an abstract representation of agents' behavior and function. Role binding mechanism is that give the role to the agent and the agent has the properties, behavior and activities schedule of the role, etc. In artificial society, we could bind multiple roles to an agent. And according to the simulation needs, one or more roles can be dynamically bound to an agent. With the advance of a continuous evolution, the agent will enter one or more new roles and go out of some roles. For example, after graduation some students will exit form the student role and may enter into the teacher role.

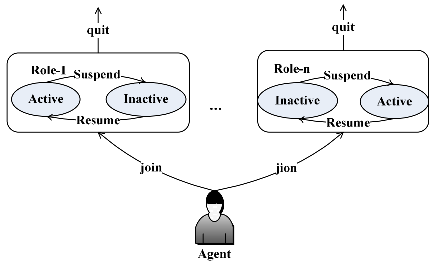

Fig4. Role binding mechanism

3.4.2 Emergency binding mechanism

Emergency model binding mechanism will give some properties and changed schedule of the emergency model to an agent, and the agent will suspend the activities schedule during normal circumstances. In the real society, many emergencies may exist at the same time. For the artificial society, a variety of unconventional emergencies may also act on the same agent. Therefore, we support that multiple emergencies models could dynamic bind on an agent. After the elimination of an emergency, the emergency model will dynamically unbind from the agent, thus the agent will exit the emergency model.

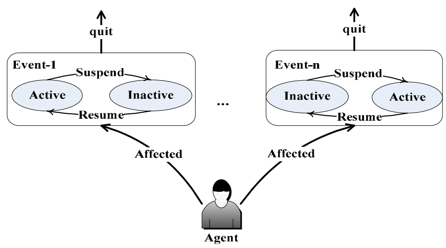

Fig5. Emergency binding mechanism

4. Case Study

Unconventional emergencies - H1N1 outbreak mentioned in section 2.3, we focus on a university campus to establish its artificial society model. Firstly, give the statistical model of agent model, including the total population: 10,000 people, male and female sex ratio: 1:1, and the proportion of roles is shown in Table 1 and the age distribution is shown in Table 2.

Table1. The proportion of roles

Roles	%
Teacher	30%
Student	50%
Service personnel	9%
Medical personnel	10%
Security guard	1%

Table2. The age distribution

Age	%
18-25	55%
25-35	15%

35-60	20%
60-100	10%

Then, give roles set in artificial society, including student, teacher, service personnel, medical personnel and security guard. We take the student role as an example to describe the student role. The student role's properties set is including college, department, class, dormitory and son on, where its activities schedule can be shown in Table 3[15].

Table3. Activities schedule of the student role

Time slice	Actions (%)
00:00-06:00	Sleep
06:00-08:00	A: Breakfast (a%) B: Exercise (b%) C: Sleep (c%)
08:00-12:00	A: In class (a%) B: Breakfast (b%) C: Self-study (c%) D: Sleep (d%)
12:00-13:00	Lunch
13:00-14:00	Siesta
14:00-17:00	A: In class (a%) B: Self-study (b%)
17:00-19:00	A: Dinner (a%) B: Group activities (b%) C: Exercise (c%)
19:00-22:00	A: Dinner (a%) B: In class (b%) C: Group activities (c%) D: Self-study (d%)
22:00-24:00	Sleep

Action set includes Dinner, Exercise, Work and so forth. The probability of stochastic interaction is 0.05. For artificial society of the campus, there are many groups, such as friends group, student union group and dormitory group, etc. For example, student union group contains group constraints (participants must be students and the university has only one student group), group composition (200 people scale), frequency of weekly activities, and activities schedule (every Monday evening from seven to nine), interaction probability of 0.7, and Action sequences can express the collective psychology student group.

Then, establish environmental agent model, and we take classroom-A as an example. Location_ID of A classroom is defined as 007, and its subordinate environment agent ID is 001 (Teaching Building B). Its geographical range is expressed as {0, 4, {(121.12223, 27.13124), … , (121.12225, 27.13128}} (height 1, height 2, and a boundary points set of its latitude and longitude). Define carrying maximum as 200 people. And classroom A is able to record the dynamic agents in the environment, and to calculate the population density of the environment and the spread probability of disease, etc.

Finally, establish the emergency model—H1N1 model, and emergency ID is 001. Actions set of emergency contains Self-test temperature, Medical care, Self-Isolation and so on. The response of different roles for H1N1 is different. For example, if students and doctors are infected with the H1N1, their activities schedule will be different. Students may continue their activities, and doctors may be self-isolation. In addition, give the additional properties of H1N1. After affected by H1N1, agent should dynamically load these properties, including immunity, vaccination conditions, symptoms, duration of symptoms, diagnostic methods used, the spread probability and so forth.

As a result, we have established an artificial society model. When an agent is infected with H1N1, the agent should bind H1N1 model and suspend the activities schedule of the role played by the agent to make the activities schedule of H1N1 model work. So agents obtain self-adaptive capacity.

5. Related work

Currently, successful international similar project is the BioWar project of United States [10] [11] [12]. BioWar is a scalable city-scale simulation platform, and it could simultaneously simulate the impact of unknown infectious diseases, natural disasters and bio-terrorist attacks (more events) to urban population. Biowar establishes the artificial society through the establishment of agent population model, agent activities model, environment model and disease model. For Biowar, there is no concept of the role, and the social relations are specified by relationship set of the agent. Meanwhile, in Biowar the environment is just the time, weather and climate, and holiday cycle (not including environmental entities, such as the classroom). Paper [13] used multi-agent technology to study the Epidemic News Spread Characteristics without the concept of roles. So agent's behaviour will not be different of roles. Paper [14] used multi-agent to study dynamics of contagious disease spread, and mainly studied disease spread model. For agent model in the artificial society, there is no concept of roles. Therefore, agents' response to disease has no difference. Meanwhile, there are no environment entities (without multi-resolution model), and agents are given only the GIS where agents locate.

This proposed artificial society model gives a more complete artificial society model, including the agent model, emergency model and environment agent model. Furthermore, we use the concept of roles that the different roles' response to emergencies is different. In a sense environmental agent model and agent model is isomorphic. So it can support multi-resolution model and simulation. At the same time, we use the concept of group to describe social relations between agents in the artificial society and the group psychology.

6. Conclusion and future work

In recent years, as the contact between international societies becomes increasingly close, the impact of emergencies has become increasingly widespread. Lots of countries are studying on the emergency management, using the method or idea of artificial society to model and simulate. In this paper, we take into account unconventional emergency management to research artificial society engineering modeling, giving a general model of artificial society, including agent model, environment agent model and emergency model to support multi-resolution model, and we propose agents' self-adaptive mechanism - binding mechanism. And the model could describe unconventional emergency management -oriented artificial society completely. The next work contains: (1) Abstract the artificial society model and propose the artificial society meta-model for unconventional emergency management. (2) At the same time, study the artificial society modeling language and model mechanism. (3) With the idea of MDA, research the automatic transforming method from artificial society model to simulation model and develop the toolkit. (4) Propose a development methodology of artificial society for the unconventional emergency management. (5) Lastly, use artificial society model, methodology, modeling language and toolkit for the engineering of artificial society (tens of millions of agents) in case of emergencies such as H1N1, SARS and public safety emergency.

7. Copyright

Acknowledgements

The authors gratefully acknowledge the financial support from National Nature and Science Foundation of China under Grant Nos. 9102403, and 61070034, Program for New Century Excellent Talents in University.

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