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Study on The Method of Multi-agent Generation Algorithm within Special Artificial Society Scene

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Abstract—**Multi-agent generation within a special scene is a basic problem for the research on artificial society. In the context of public health emergency, the multi-agent model of an artificial campus is built; based on the deep analysis of the problem, we consider that a special scene in artificial society is approximate to a polygon determined by some key points (border points). Therefore the problem of multi-agent generation is converted to inner-point generation in the polygon. The grid-based method is proposed to divide the scene polygon reasonably consistent to the density. The filtering mechanism of grids generated is proposed. Finally, the experiment shows that the method could be used to generate some agents with some properties in a special scene randomly, and has certain reference value.**

Keywords-artificial society; scene; grid method; infinite element

I. INTRODUCTION

The problem of modeling highly integrated and complex artificial society involves many aspects of natural and artificial systems, social organizations, individual psychology and behavior, with a variety of uncertainties and opposability [1]. The wide application of the computing technology and the maturity of numerical method have make it true to research the dynamics of social system in use of simulation. In early 1990s，the Land Corporation proposed the concept of artificial society, and from that on, artificial society has begun to spring up. The core method of artificial society is based on the modeling and analysis of the Agents. Its basic idea is described as following: human society is a complex system which contains a lot of individuals, and the individuals could be modeled in the computer (that is the software agent); the agents should follow certain rules of interaction; the social or group phenomena emerged by observing the whole behavior of the agents, and the model of the complex social system could be built to study information technology impact on the society, politics and culture [1, 2, 3]. The simulation of artificial society based on multi-agents modeling has become an effective solution to solve complex social systems.

In recent years, various unconventional emergencies have occurred one after another in China, and emergency management has become the major challenge to the social management. The method and technique of computer simulation used to build the scenario of the incident's happening, development, transformation and evolution has been considered the most important way to solve "scene-response" problem of unconventional emergency management. The research has been carried out abroad for some years. Arizona State University in the United States built a 8000 square feet named Decision Theater for decision support in the emergency scene in 2005. In 2007 and 2008, the U.S. Department of Homeland Security implemented the Golden Guardian for the terrorist attack and earthquake in California. The key component is the Exercise Control System to support scenario generation, learning and training, tissue remodeling, and so on [4, 5].

The scene could be considered as the environment and condition where the agents are located in artificial society, while usually the agents are constrained to act in a special area. The paper mainly studies the random generation of agents with some particular characteristics within the special scene of artificial society, and the groundwork is built for the next research.

II. MULTI-AGENT MODEL

Based on the complex network modeling technology and the real system information acquisition technology, multi-agent system could be introduced to describe the groups and individuals in human society, which could provide the good technology ground for recurring the complexity of the social system, and approaching the social context of unconventional emergencies [6]. While social system is the complex system which contains a large number of intelligent agents, the method of agent-based modeling and simulation is feasible to describe the individual or group behavior, and analyze the social structure evolution and group behavior law with the interaction between agents. Multi-agent system is composed of many agents interacting with each other. There are also some interactions between agents and environment. Generally, each individual agent could make decision independently, and has the ability of adaptive, learning and cognition [7, 10].

The paper mainly focuses on the spread of infectious diseases within a campus, and builds the artificial campus in the context of unconventional public health emergency. The population agent in artificial society should be set the basic demographic attribute to establish the population statistics model within a specified scene in use of the population census statistics. The agents with different demographic attributes and different spatial distribution could be generated automatically in geography environment. Agent modules in a campus include population statistics model, agent behavior model, disease-related model, the social relationship model, and agent interaction model [8-10].

$$Agent_{individual}:\begin{cases} demography\ model(t) \\ activity\ model(t) \\ disease\ referred\ model(t) \\ social\ relationship\ model\ (t) \\ communication\ model(t) \end{cases}$$

The agent's population census statistics can be described from two aspects. One is public population census attributes, owned by any agent in any application area, such as ID, sex, age, role, and so on ; the other is domain-related population census attribute, for example, in public health event, including the immunity ability, symptoms, duration of symptoms, spread probability, and so on.

The agents in artificial society can be categorized according to the role of population census. A class of agent represents a kind of entity in real world. Based on the agent model with public population census attributes, the special attributes and behavior rules can be added newly. For example, except for the basic attributes (ID, sex, age) for the student agent, the special attributes (grade, professional, class) and related behaviors (entertainment, community activities, sports) should be added. A common agent could be described as shown in fig.1.

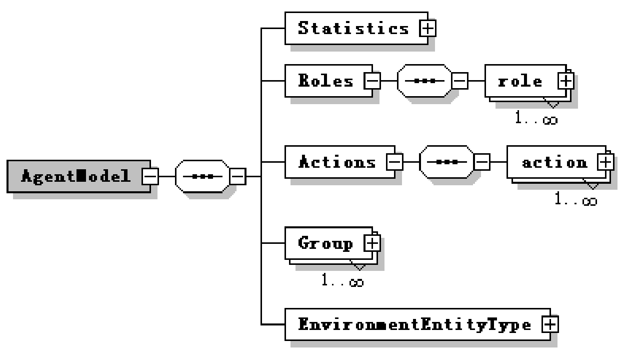


Figure 1. Agent model

III. BOUNDARY OF SPECIAL SCENE

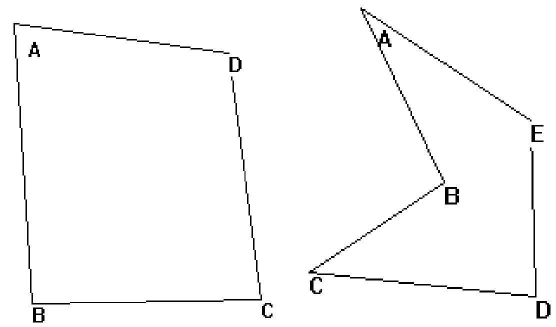
A. Setting the Boundary

The scene is the place where the agents act, and has its own boundary and constraint. The agents always act within a certain area, and execute some related activities.

There are some criteria to justify the algorithm. The agents must be generated inside the scene, and the distribution of different agents should be consistent with the density of different agent in the scene. In order to determine the scene boundary, the coordinate of some key points which reflect the boundary shape should be given, and the scene can be generated based on the points. Especially for the complex shape, it's feasible to depict the scene in use of polygon approximation, and in error permission the complex shape between two points can be approximated by a straight line segment [13]. For the sake of simplicity, the scenes generated in the paper are closed polygon shape.

Given a point array $\{(x_1,y_1),(x_2,y_2),\cdots,(x_n,y_n)\}$, the algorithm generating n edges shape is described as following: firstly, the index counter should be defined, and record the number of connected nodes. The initial state of the index counter is Zero. Secondly, the point $P(x_p,y_p)$ selected from n key points ($1 \le p \le n$) is regarded as the start point, and the index counter should be added by 1. Then the adjacent points should be connected in sequence. Whenever a point is connected, the index counter should be added by 1. In the step the closure of polygon should be judged. If the value of the index counter is greater than n, and the point returns to the start point, the shape could be considered to be closed. So the lines between adjacent points as the sides of polygon are regarded to be the boundary of the scene.

Usually, the expressed way of the polygon in the computer is to sort the order of adjacent vertices arranged in an array. When shown the vertices can be connected by a straight line according to the store order. Geometry shape is ultimately described by the polygon.



(a) (b)

Figure 2. Polygon generated

B. Judging the Relationship between Points and Scene

After the boundary of the scene generated, the activity range is determined in artificial society. It's important to make sure that agent should act in a special area, and can't exceed any boundary. The section mainly proposes the ray method to judge the relationship between the points and scene through refining an agent to be a single point in geography space.

At present, the ray method is the most widely used to judge the space relationship between points and polygon in engineering area [15, 16]. It's basic principle is described as following: Given a judging point P, the ray L is drawn along the direction of the polygon from the point P(Generally the ray parallels x axis or y axis); then the number of the intersection points is calculated. The relationship could be judged according to the parity of the number. That is the "odd number internal, even number external" rule. However, the rule isn't always suitable for any condition. There are still some special conditions to deal with.

(1)If the ray and a polygon vertex intersects, and two sides of the vertex lie in both sides of the ray L, the number of the intersection points is just one;

(2)If the ray and a polygon vertex intersects, and two sides of the vertex lie in same sides of the ray L, the number of the intersection points is Zero;

(3)If the ray L comes across two adjacent vertexes in succession (It means that the ray L superposes a side of the polygon), the two vertexes could be considered an intersection point. According to the computing method described in condition (1)(2), if the two fore-and-aft vertexes of the intersection point lie in different sides of the ray L, the intersection point should be regarded one point added to the number of the intersection point; otherwise, it can't be computed.

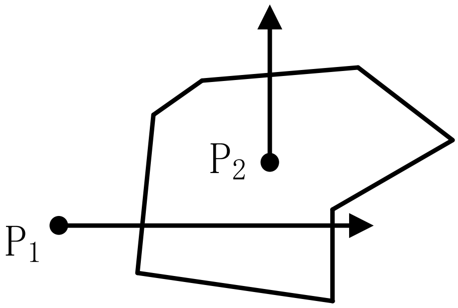


Figure 3. Ray method

The ray could always come through the polygon, because the polygon is bounded. Based on the ray method, the algorithm process could be described as following:

(1)Given the start point $P(x_p, y_p)$, and the polygon formed by a point array $\{(x_1, y_1), (x_2, y_2), \cdots, (x_n, y_n)\}$;

(2)The ray $y = y_p, x \in (x_p, \infty)$ paralleling x axis is drawn from the start point $P(x_p, y_p)$;

(3)Each side $S_i((x_i, y_i), (x_{i+1}, y_{i+1})), i \in [0, n)$ of the polygon is obtained circularly, and there should be some needs to judge whether each side parallels x axis. If paralleling x axis, enter into the next step; otherwise, continue to cycle;

(4)Priority is to judge whether the point $P(x_p, y_p)$ lies on a side of the polygon. If it is, it's thought that the point lies in the polygon and return true, otherwise enter into the next step;

(5)Judge whether the ray $y = y_p$ and the vertex of the polygon intersect. If it is, the position relationship among the ray and the two sides of the vertex can be judged by comparing the abscissa of the vertex with $P(x_p, y_p)$, and if the position lies in different sides, the intersection point counter should be added by 1, otherwise the counter can't be changed; if not, enter into the next step;

(6)Judge whether the ray $y = y_p$ and a side of the polygon overlap. If it is, it could be considered an intersection point. If the adjacent vertexes of the ersatz point lie in the different sides of the ray, the ersatz point can be regarded as a intersection point added to the counter, otherwise the counter unchanged. If not, enter into the next step;

(7)Judge the ray and a side of the polygon intersect. If it is, the intersection point counter should be added by 1; otherwise return to the third step;

(8)Judge the overall number of the intersection points. If the number is odd number, it means the point P lies in the polygon and return true; if even number, it means the point P lies outside the polygon and return false.

IV. GRID METHOD

Obviously, it's very important to generate some inner points within the scene automatically and randomly. As described above, the auto generation of the inner points within a scene is transformed into the auto generation of the inner points within a polygon. Recently the generation technology of the inner points within a polygon has been developed, such as the approaches based on triangle and MBR [11, 12]. These approaches have made good attempts to solve the problem of inner point generation and received ideal effects. However, the algorithm process may be so trivial and complex that too many computing resources are consumed. We proposed and introduced grid method to make sure that individual agents be ergodic and diversiform, but also not increase the scale of the inner points blindly.

A. Grid Density

The basic idea of grid method is described as follows: according to the boundary of the scene polygon (for example, the value range in x axis or y axis), the scene polygon is divided into many interzone boundaries. All the interzone boundaries are intersected to form many small quadrilateral grids. The intersection points in the quadrilateral grids are the point in search space, as shown in fig. 4. When the initial points are generated, individuals can be full of the whole search space.

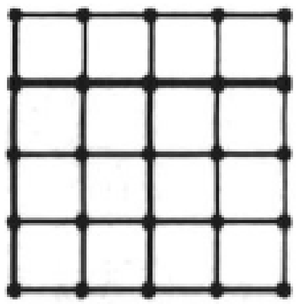


Figure 4. Grid method

In artificial society scene different area might have different population distribution density. There are some concentrated and collective phenomena in real world. It must require that the density of the grid should be considered when the scene is divided.

For the algorithms of quadrangle grids, the most representative is geometric decomposition method. Within it the two best methods are Looping and Paving, while it's hard for the two methods to control the grid density. In order to reflect the density differences among the grids, it's required that the density control should integrate with geometric decomposition.

The density of the grid can be defined as the reciprocal of the grid element length from the view point of mathematics. We adapted Laplace equation to express grid density distribution function within artificial society scene. Grid density distribution should be continuous in the area divided. It could ensure that the grid elements generated based on the grid density have the property of catholicity and universality [13, 14]. Given the grid density $U(x,y)$, the Laplace equation of the grid density distribution function can be described as following:

$$\frac{\partial^2 U}{\partial x^2}+\frac{\partial^2 U}{\partial y^2}=0 \qquad (\text{in } \Omega) \tag{1}$$

Where Ω means the area of the scene.

The boundary condition of Eq. (1) is expressed as:

$$\frac{\partial U}{\partial n}=0 \qquad (\text{on } \Gamma) \tag{2}$$

Where Γ is the boundary of the scene; n is normal direction of the boundary Γ.

Numerical solution of Laplace method can be attained in use of the finite element method [14]. In order to attain the grid density of certain area, the area should be divided into discrete computing elements. As shown in fig.5, the scene is a hexagon area. Based on the minimum rectangle carving, the elements outside the scene are removed, and the scene area is divided into the computing elements.

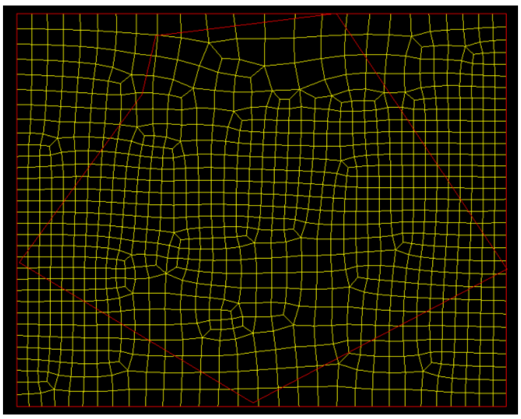


Figure 5. Scene division

The density of each point within grid elements is solved by the interpolation of the density of grid's four vertexes. The shape functions of the four vertexes are described as [14]:

$$\begin{cases} q_1=(1-\xi)(1-\eta)/4 \\ q_2=(1+\xi)(1-\eta)/4 \\ q_3=(1+\xi)(1+\eta)/4 \\ q_4=(1-\xi)(1+\eta)/4 \end{cases} \tag{3}$$

The density of any point can be expressed as:

$$u(\xi,\eta)=\sum_{i=1}^{4} q_i(\xi,\eta)u_i \tag{4}$$

Where ξ,η are normalized coordinates of elements; u_i is the density value of ith node.

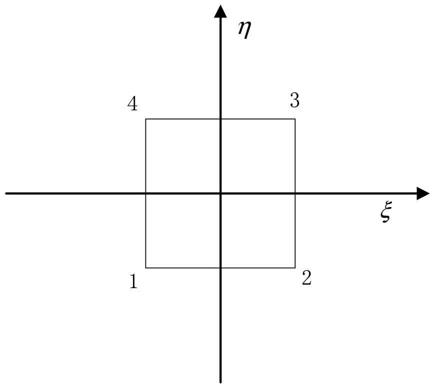


Figure 6. Grid element

Under the known boundary conditions, Eq. (1, 2, 3, 4) are united to solve the density of elements. In fact, the boundary condition of density is equal to determining the density value of the boundary points. The density value of the boundary points can be attained according the curvature. Because the area of the scene is expressed by diagnostic polygon, the length of each side in diagnostic polygon can roughly reflect the curvature of the boundary [13,14].

The division of the grid would need to consider the human activity scale, and the number of the grids divided could be given ahead of time. According to the grid density distribution, the nodes are generated in the boundary. The nodes lie in the sides of diagnostic polygon, generated between two key points. Then these nodes are numbered sequently according to the order. There need to be two steps to complete the process: the first is computing the number of the nodes; the second is determining the location of the nodes.

B. *Computing the Number of Node*

In order to compute the number of the nodes generated, the integral for the density should be made along two key points, shown as:

$$\int_L u(s)ds = R \cong N-1 \tag{5}$$

Where N is the overall number of the nodes including two vertexes; L is the connected line between two vertexes; u(s) is the boundary density.

In actual numerical computing, Eq. (5) could be computed according to the following method: the line L can be divided into some same line segment. The density in the middle of the small line segment is regarded as the mean density. Product by multiplying the mean density and the length of the line segment sums into the approximate integral result R. As a real number, the integral result R should be rounded up to the nearest integer N-1. In addition, the overall number of the boundary nodes must be an even number. So to meet the demand, there need to be adjust N. As the result of round, there must be some errors between the grid unit number and setting value.

C. Determining the Location of Nodes

The finite element iteration technique is used to determining the location of the nodes. Except for the beginning and end nodes, the others are unknown. The location of the nodes(relative to the start point of the length) can be regarded as a dimension variable and the variable should meet certain equation:

$$u(s)ds = Ad\varepsilon = C \tag{6}$$

Where $u(s)$ is the boundary density function; $d\varepsilon$ is the derivative in computing space (the nodes meet the even distribution in computing space); A is the proportion constant; C is the constant.

The Eq. (6) could be transformed into two-order derivative equation, shown as:

$$\frac{d}{dx}\left[u(s)\frac{ds}{d\varepsilon}\right] = 0 \tag{7}$$

In Eq. (7), the numerical value could be solved in use of emergence element iteration technique. The computing space is divided into N-1 units. Through the unit analysis, the unit stiff equation could be described as:

$$u[\tfrac{s_i+s_{i+1}}{2}]\begin{bmatrix}1 & -1\\ -1 & 1\end{bmatrix}\begin{bmatrix}s_i\\ s_{i+1}\end{bmatrix} = \begin{bmatrix}0\\ 0\end{bmatrix} \tag{8}$$

Where s_i means the location of the ith node.

The whole stiff equation can be attained by fitting all the unit stiff equations together. The location of the first node is set $s_1 = 0$, and the location of the Nth node is set $s_N = L$ (the length between two key points). The others are assumed to meet the even distribution. The location of each node could be attained by solving the whole stiff equation iteratively.

D. Generating Randomly

In the paper we use middle-square method to generate the stochastic number. The square method firstly starts from some initial seeds. Based on the algorithm of the square method, false stochastic array could be acquired. After generating false stochastic number, R_{new} is defined according to the number of elements selected in the scene, described as follows:

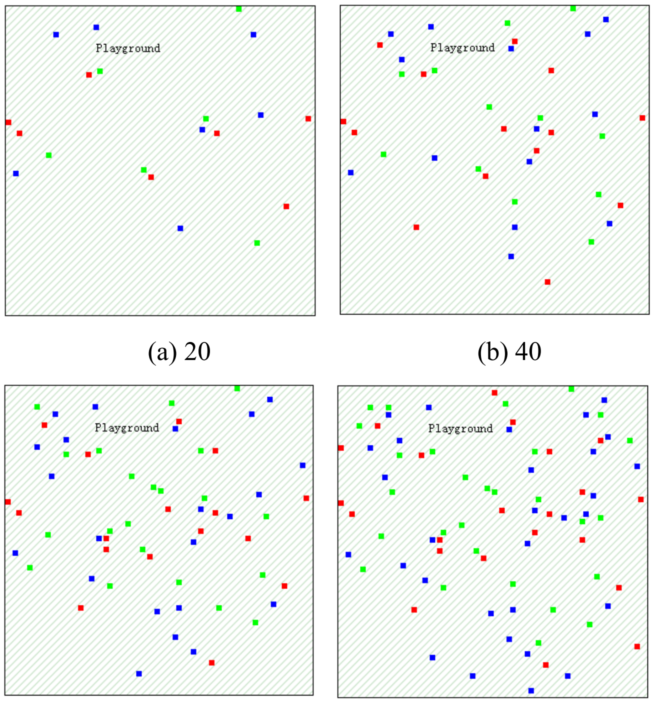
$$R_{new} = rand()/(N-1) \tag{9}$$

The points in the grids can be indexed from the selected grids. The whole process is random, done completely by computer.

V. EXPERIMENT

The experiment has implemented the auto generation of student agents within the playground artificial campus in the context of public health event. The playground boundary is formed by some key points known firstly. According to the daily statistical data, the personnal distribution is set reasonably.

For simple, the playground is regular rectangle, and the playground scene is divided uniformly. Here, 20, 40, 80 and 100 agents could be generated in the playground respectively given ε=σ=4, as shown in fig. 7. The red point, blue point, and green point represent three kinds of students respectively. Through computing, at the first time the number of the grids selected is 7715. After further selected, the final number of grids is decreased to 7056. The integer introduced in the process of computing the grid number results in the number reduced. Meanwhile the integer leads to error.



(a) 20 (b) 40

(c) 60 (d) 80

Figure 7. Playground Scene

As shown in fig.7, all the agents are almost generated in the playground, and there could be different density in the different district. The simulation has justified the algorithm effectively.

VI. CONCLUSION

In the paper, we proposed a grid method, fully considered different distribution density within the actual scene, and adapted a division way to reflect agent's distribution. The experiment result showed it don't only generated agents randomly, but also ensured that the agents be ergodic and real. However, we just discussed the auto generation of multi-agents within artificial society scene from the view of 2D, and made some simplification in the process of generation. It's unavoidable that there are still some errors and infects to improve. With the development and maturity of computer and simulation technology, the future construction and implement of the artificial society must face to a wide prospect.

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