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Research on the simulation of fish behavior based on swarm intelligence

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ABSTRACT

Swarm intelligence is an intelligence emergent phenomenon that the simple individual interactions of nature biological groups result in complex intelligent behavior. In this paper, the problem of fish behavior evolution is aimed at, the vector model based on the multi-Agent fish swarm environment, the main body and the behavior regulation have been established by the analysis of fish moving, looking for food and so on. The synthesis algorithm which is used to confirm the direction and speed of a single fish in the process of group behavior evolution, and the framework model of fish swarm behavior evolution is established. Finally, the proposed algorithm is proved to be reasonable by simulation experiments.

KEYWORDS

Fish behavior;
Evolution;
Model;
Simulation.

INTRODUCTION

The research on swarm intelligence theory has appeared since the 1980s and has obtained more and more attention as an emerging domain. The swarm intelligence mainly studies the group behavior of the group living creatures such as ants, birds and so on. Being inspired by the intelligent phenomenon of group behavior in natural biology community, it is a specific research pattern studying the simple biological community's intelligence, namely the characteristic of the simple intelligent individual displaying the complex intelligent behavior through interaction.

Group behavior simulation is always a challenging research. In twenty-first Century, large-scale group simulation technology has been rapid development. The computer science professor ErikAndersen in University of North Carolina has study the real-time path planning of multi-agent dynamic virtual environment, and the method of using Voronoi data structure for motion planning and demonstration of the path and motion planning with dynamic obstacle avoidance of the city groups of people is proposed, the data structure of Voronoi exhibits good performance[1]. The more famous in the aspects of group behavior modeling is the social force model based on physics[2], this model describes relationships between individuals of group people in physical, the movement behavior of individual is determined by a variety of forces, these forces include driving force, avoid other people or objects to the target, the repulsive force and attractive force of export. The model of Pelechano referred to social force model is used to simulate high density population emergency evacuation scenarios, and the scenes of the crowd automatic distribu-

tion in the opposite direction, non-panic automatic queuing and panic state crowd are described[5]. The OCEAN personality model is put forward to improve the credibility of crowd animation by Durupinar, this method mainly discusses some distinguished individuals scheme, there is no specific discussions on how to escape the crowd personality to drive the behavior[6].

This article studies the group behavior of fish swarm through the multi-Agent system in which the individual fish is regarded to be Agent, and the fish swarm is a multi-agent system. Agent can sense local environment and information in the field of vision scope, thus making a decision to instruct its motion.

THE ANALYSIS OF THE FLOCK BEHAVIOUR OF FISH SWARM

The behavior description of the fish swarm is composed of the environment, the main body and the behavior rule, mainly including food, fishhook and the two kinds of fish. The environment is the space of individual existence in which the agent moves and collects resources (food). The total sum of the individual constitutes the community object of the research. The individual's evolutionary process is controlled by its behavior rule. The behavior rule has decides the interacting methods between the individuals and between the individual and the environment. The individual survives depending on food resources and the consumption of its own energy. At any time there always is a set position for the individual in the environment.

The position is determined by the direction it occupies. Since the individual of the community intelligence research only has simple intelligence or does not have intelligence at all, their ability to sense the environment is very limited, therefore the individual should also have certain perception area, in which each individual can sense other individual's acting situation as well as the resources distribution in the environment and knows nothing outside the perception area. The individual collects resources to prepare for energy consumption in the future. The individual may die of hunger or may be fished by fishhook and dies (ordinary fish are also possibly preyed on by others). Between fish swarm, they interact according to the respective behaving rules, hence creating a macroscopic phenomenon and result. The

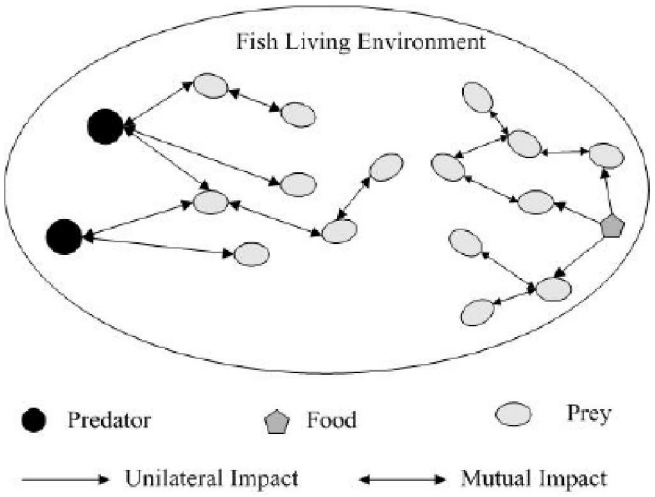

Figure 1: Fish living environment

relationship between various main bodies interaction can be shown in Figure 1.

THE DESCRIPTION OF THE BEHAVIOR OF FISH SWARM IN THEIR ENVIRONMENT

When the simulation is carried on by the computer to study the behavior of fish swarm, the activity environment of fish swarm may be defined as a limited two-dimensional surface region, using reflective boundary, to which the fish tours to and then bounces back. The concrete environment description is like the following: in a two-dimensional flat world constructed by width and length, a series of movement spot replaces the individual fish through the contact surface on computer. When the parameters of coordinates, speed, and so on are established for those movement spots, the real fish can be mapped in the virtual environment, and then it is possible to describe the fish swarm individually to move about and seek food in this region.

The description of the position and the direction of individual fish swarm are as follows:

$$\begin{cases} v_x = v \cdot \cos(direct) \\ v_y = v \cdot \sin(direct) \end{cases}$$
$$\begin{cases} x' = x + v_x \\ y' = y + v_y \end{cases} \quad (1)$$

Here v_x is expressed as the individual velocity component in the direction of x, v_y is expressed as the indi-

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vidual velocity component in the direction of *y*, direct is expressed as the swimming direction, namely the included angle of the swimming direction and *x* axis. (*x*, *y*) is expressed as the coordinate of target location.

The simulation environment on computer also includes information of food, bait and so on. This kind of information may be stored by defining an array variable world[*x*] [*y*]. World[*x*][*y*]=0 expresses this spot has no element, world[*x*][*y*]=1 expresses this spot is food, world[*x*][*y*]=2 expresses this spot is bait.

OBJECT DESCRIBE

In the research of the behavior of fish swarm, the core and the key is the individual modeling. This research regards each fish as Agent who is an independent policy-maker. They will sense the environment by observation, and will size up according to certain rules.

Three kinds of subjects are defined in Figure 2: Fish, food and hook. Among them, the subject of fish includes ordinary fish (Pfish) and predator class (Hunter).

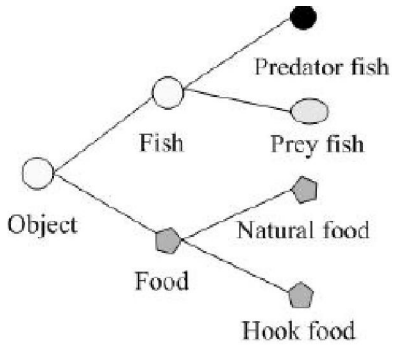

Figure 2 : Object categories

Fish

Fish survives on environment, collecting resources from the environment to increase their own energy content. The interaction between individuals is partial, decided by its perception range. Their interaction can only occur in the neighborhood, which may be defined by the function of food-seeking condition.

$$S(t) = (E_0 - \mu + E_t\alpha)/E_{max} - \beta = \begin{cases} \geq 1 & \text{the state of repletion} \\ \leq 0 & \text{the state of death} \\ \text{others} & \text{the state food - seeking} \end{cases} \quad (2)$$

And, E_0 is expressed as the initial energy, μ is expressed as the consumption energy in unit interval/unit time, is expressed as food energy, α is expressed as the amount of food that this Agent eats at the moment of t time, β is expressed as the amount of bite that this Agent eats (only to take 0 or 1).

Food

Food has the static attributes as follows:

- Energy: the energy content contained by each food is also the amount of energy that may provide to the fish.
- Location (x_{feed} , y_{feed}): used for determining the position of food in environment, expressed by their coordinates. Food will not move, therefore the coordinate will not change.
- Color: the color that food demonstrates in the environment. It is set red in this model. The template is used to format your paper and style the text.

Hook

Hook has the static attributes as follows:

- Color: The hook subject displays colors in the environment. The color is set as the yellow in this model.
- Position: Using for determining the position of hook subject in the environment, indicating it according to the coordinates, the hook subject cannot move, therefore, the coordinates will not change.

Rule description

Each fish must observe three rules (approach the centre of the neighbor as far as possible, consist with the direction of the neighbor as far as possible, and avoid collisions as far as possible), these three rules can play a part in changing the direction of fish swimming in next moment, the fish swimming cannot change immediately, and also show some kind of inertia function. According to the average direction of the four directions as the fish swimming direction in next moment. Because the direction is the included angle with horizontal direction, therefore, it only needs to average the included angle of the four directions and horizontal direction, which means, the fish swimming direction in next moment.

The formula is expressed as:

$$D_{t+1} = D_{1t} + D_{2t} + D_{3t} + D_{4t} \quad (3)$$

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In the formula, $\mathbf{D}_{t+1}$ is the Agent's swimming direction in next cycle. $\mathbf{D}_{1t}$ is Agent's swimming direction in cycle *t*, D_{2t} is the current individual to the direction of neighbor's average position in cycle t, D_{3t} is the average direction of neighbor's, D_{4t} is the neighbor which less than collision distance to the average value of current individual's direction (Figure 3). In consideration of various rules have different influence for fishes, we need to weighting each direction to get the average value of weighting, the size of weight may determine according to the preference.

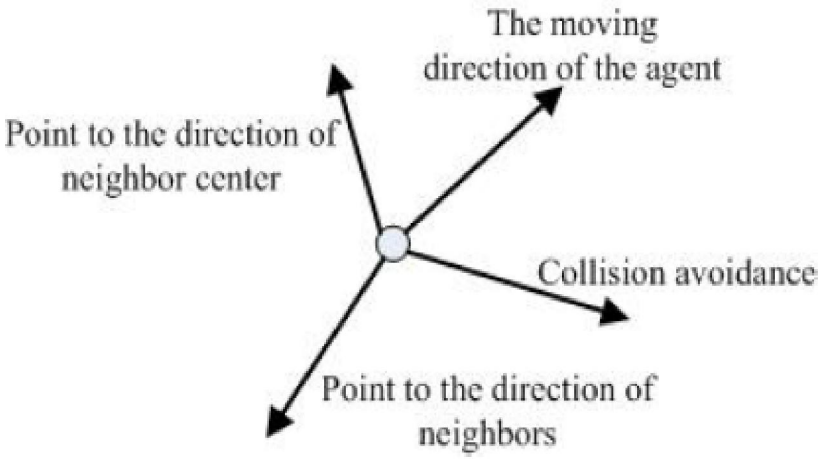


Figure 3 : Fish swimming direction

$$\mathbf{D}_{t+1} = \lambda_1 \mathbf{D}_{1t} + \lambda_2 \mathbf{D}_{2t} + \lambda_3 \mathbf{D}_{3t} + \lambda_4 \mathbf{D}_{4t} \quad (4)$$

Where $\lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 = 1$ 0

Describing the three swimming rules separately as bellow:

The centrality (approaches). Each individual has the characteristic to close up the neighbor center; the neighbor center is the average value of individual among the range of observation.

Formula is expressed as:

$$\bar{\mathbf{P}} = \frac{\sum \mathbf{Pi}}{|\mathbf{N}|} (\mathbf{i} \in \mathbf{N}), \mathbf{D}_{2t} = \arctan \frac{\bar{\mathbf{y}} - \mathbf{y}_0}{\bar{\mathbf{x}} - \mathbf{x}_0} \quad (5)$$

$\bar{P}(\bar{x}, \bar{y})$ is the average value of neighbor, $P_0(x_0, y_0)$ is the current individual's position, $\mathbf{P}_i$ is the each current neighbor's position, $\mathbf{D}_{2t}$ is the current individual position to $\bar{\mathbf{P}}$ direction.

The isotropy (aliens). The individual will swim in the same direction with its neighbor.

Formula is expressed as:

$$\mathbf{D}_{3t} = \frac{\sum \mathbf{Di}}{|\mathbf{N}|} (\mathbf{i} \in \mathbf{N}) \quad (6)$$

$\mathbf{D}_i$ is each neighbor direction, N is neighbor number, $\mathbf{D}_{3t}$ is the average direction of neighbor.

The repellency (avoids collision). When individual gets close to it neighbor (the distance is shorter than collision distance), should avoid automatically.

Formula is expressed as:

$$\mathbf{D}_{4t} = \frac{\sum \arctan \frac{\mathbf{y}_0 - \mathbf{y}_i}{\mathbf{x}_0 - \mathbf{x}_i}}{|\mathbf{M}|} \quad (7)$$

$\mathbf{D}_{4t}$ is the average value that the neighbor which less than collision distances to the current individual direction, M is the neighbor number which less than collision distances among the neighbors.

APPLICATION SIMULATIONS

This simulation system establishes from bottom to up which adopts the artificial life method, may describe the fish school's swimming in the ocean effectively, as well as behavior changes of the individual's which input food. When environment change, fish individuals generate different behavior along with the environment, which reflects the individual's adaptability to the environment. The analysis process is put forward in the study of group behavior evolution problem as Figure 4.

Based on multi-agent modelling techniques, the method of multi-agent class is introduced during establishing fish behavior simulation model in order to re-

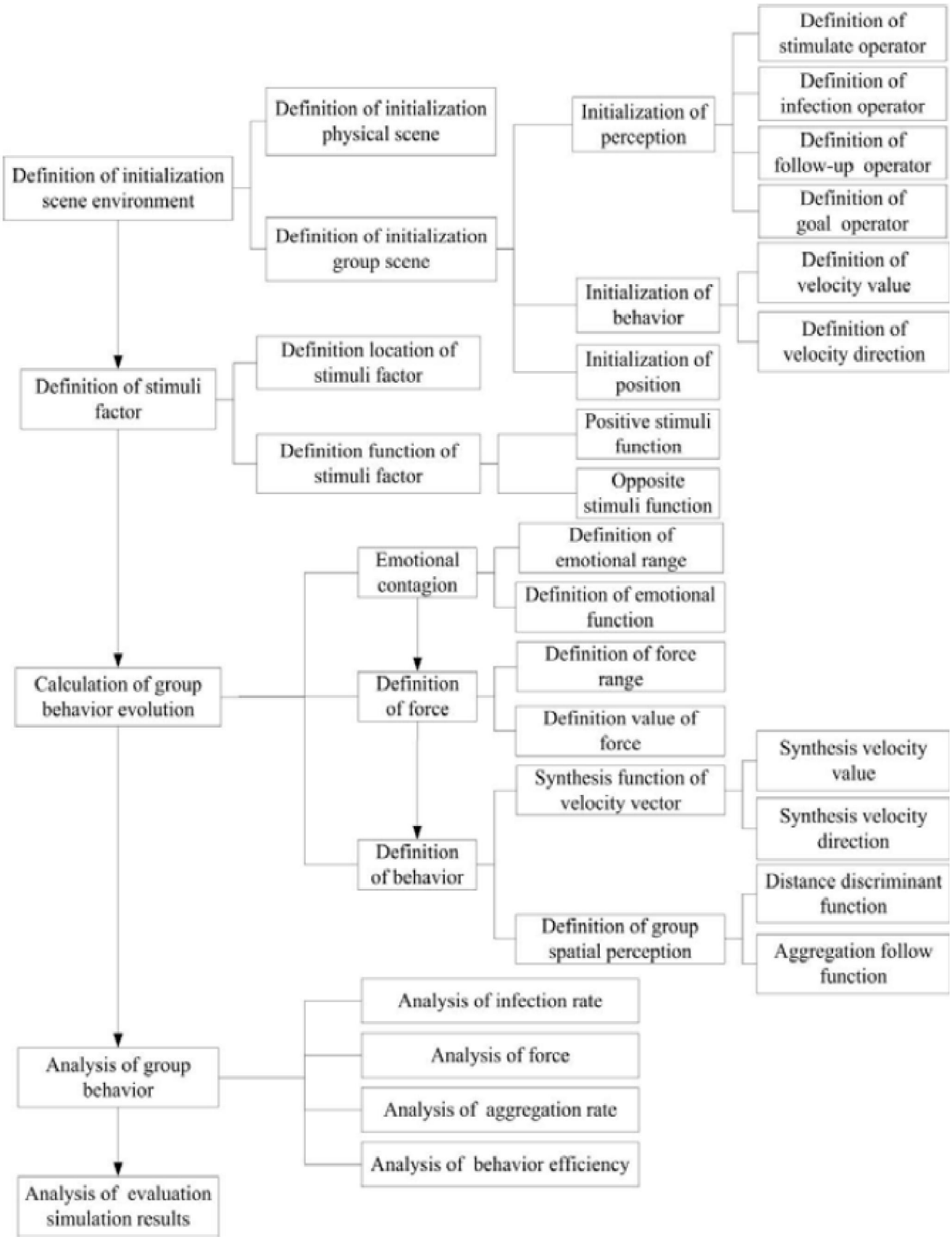


Figure 4 : Analyzing process of behavior evolution

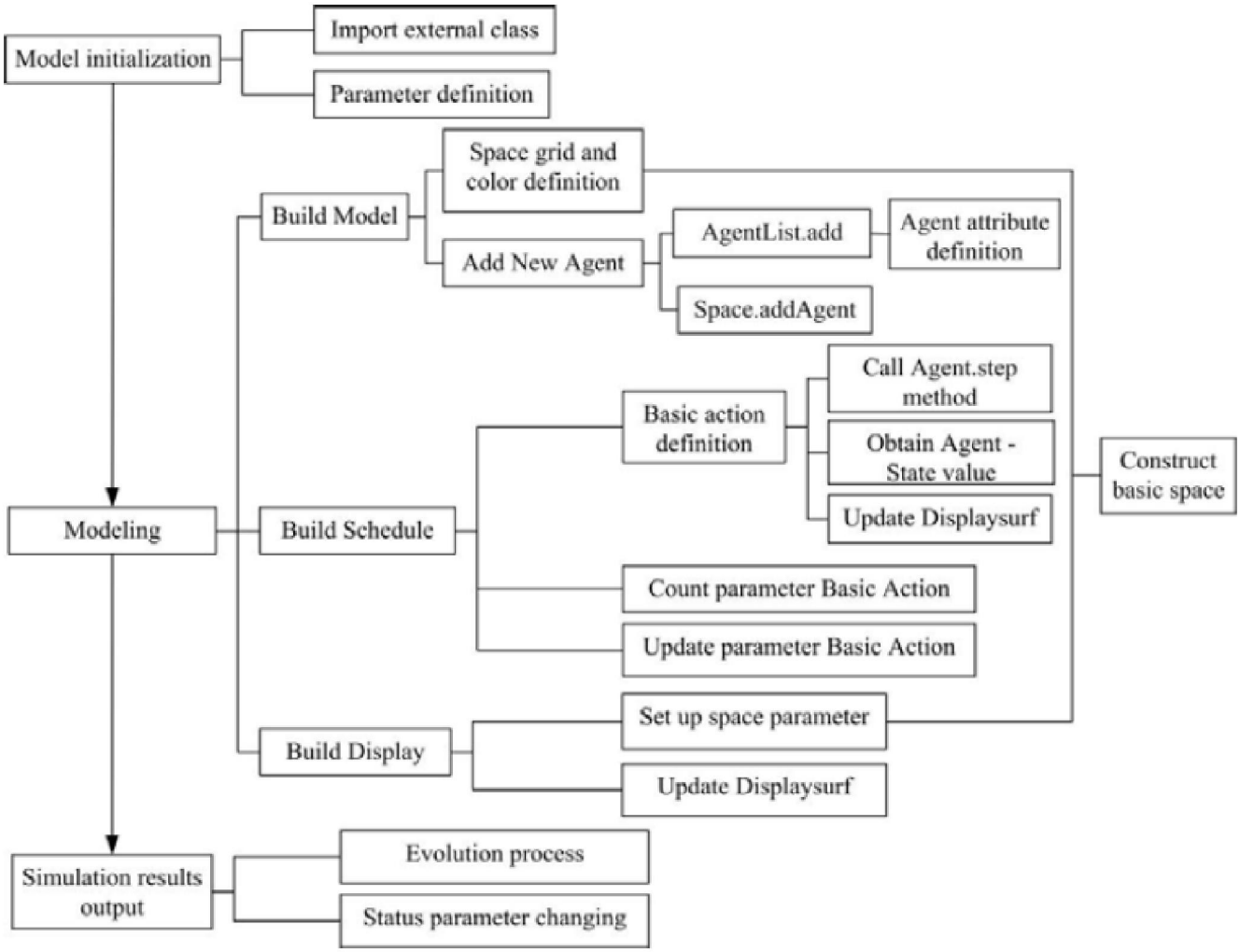
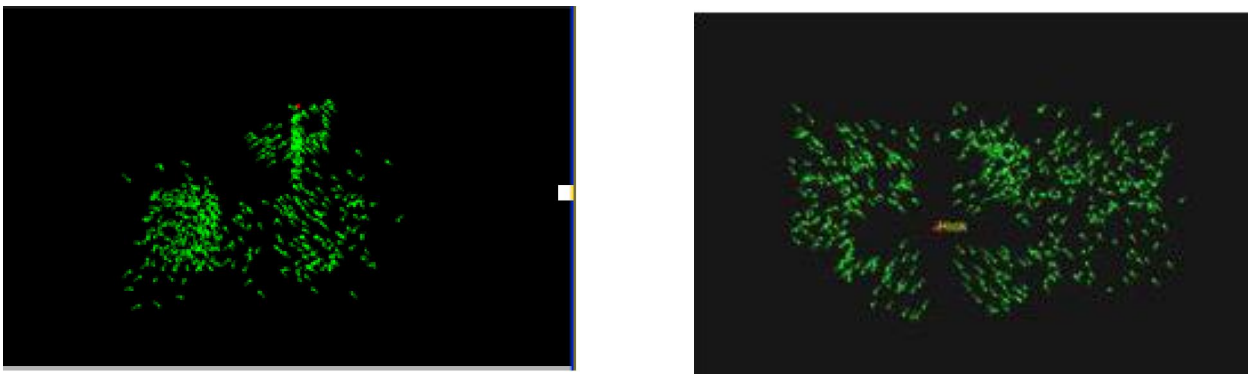


Figure 5 : Process of simulation modeling



(a) Hurl food state **(b) Fish flee hook**

Figure 6 : Simulation result.

duce the scale of model definition, the basic process is shown as Figure 5.

The results can be seen, the original state individual distributes in the environment randomly, has the random city. After passing several stimulation cycles, because of observing the swimming rules to swim, which have the individual aggregated result. Each stimulation cycle (Figure 6), individual must consume own energy to maintain the survival, when the individual energy content depleted, this individual death. Finally, all individu-

als will die for energy consumption.

CONCLUSION

The community intelligence is a kind of modeling for the bottom individual which only possesses the limited perceptible ability, these individuals follow the simple behavior rule, and the complex group behavior is the characteristic which completely emerges spontaneously from bottom to top. Therefore, may establish the stimulation model of animal groups in computer; achieve the aggregated emergence effect through computer's model interaction. In this article, according to establish stimulation model for fish behavior which contains two kinds of fish subjects that have reproduction ability and preys on relational. Fish swimming, inputting food and bait are all stimulated, and then obtain the relevant data. It may stimulate different effects through setting up different stimulation parameters. This work was supported by science and technology key research of BeiJing educational commission.

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