Simulation for Species Plaque Evolution in Food Chain Based on Cellular Automaton

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***Abstract*—**This paper utilizes cellular automaton to simulate the evolutionary axiom of species plaque within a food chain, particularly the evolution of plaque number. First, we define species plaque. Then we use the cellular automaton to construct simple food chain to process simulation and finally analyze the data from the evolutionary process. We find that when species number in a food chain has stabilized, the plaque number of different species will present in a stable form.

***Keywords*—**Food chain, cellular automaton, species plaque, stable form.

I. Introduction

FOOD chain is a linear relation that starts from the basic producers and ends with the peak predators, or the decomposers. Food chain can show the relationship between species through their recipes and each layer of it represents different trophic layers.

Food chain is different from food web because every layer of food chain only composes of one single species while food web is the product of complex relations between various species. Food chain is first mentioned by African-Arab scientist and philosopher Al-Jahiz, and was later published in a 1927 published book written by Charles Elton. This book also gets an idea of food web theory. [1-4]

Cellular Automaton (CA), a model with self-replication function and capable of simulating life system, is first mentioned by John Von Neumann in 1960s and is a model of simple structure, loose spatial and state variables and limited states.

Dewdney (1984) may be the first person to use CA to study the predator and prey systems[5]. He uses the cellular system on a cyclical phase and John Von Neumann neighbor (up, down, left, right four directions) to study the Shark-fish system. Then, studies on this direction started to flourish.

Normally, cellular automaton is used to simulate the species change in a food chain, but there do have some different ones. For example, Robert M. Itami (1994) used cellular automaton to simulate the density of species [6]. Hawick (2010) conducted spatial analysis on predator-prey system of two species in a zone of 100,000 units big.[7]

Zhu Gao (2013) uses cellular automaton to conduct quantity simulation on predator-prey system of three species [8]. Our article is based on the program in essay [8] and uses cellular automaton to simulate the evolution of patterns, focusing on the axioms of quantity and size change of patterns associated with time.

II. Definition of Species Pattern

For simplicity, we create a 6*6 two-dimensional cellular space with only one species, like figure 1. Black cell means that it has been occupied by species.

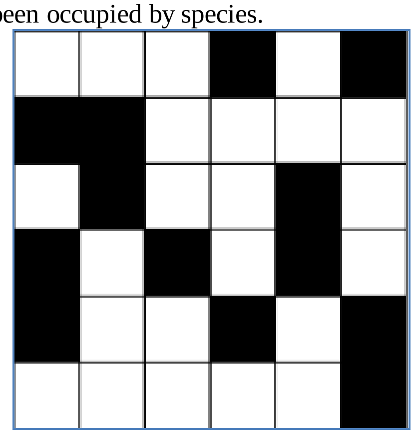

Fig 1 Example of pattern

If those occupied cells are side-by-side, then they form a pattern. The idea of side-by-side is congruent with cellular automaton, which uses Von. Neumann style here (up, down, left, right four neighbors)

In figure 1, there are 8 patterns, from up to down, from left to right, the according areas of the eight patterns are 1, 1, 3, 2, 2, 1, 1, 2 units, with the greatest area 3.

III. Simulation And Computation Method

A. Model hypothesis

We use the same method as in essay [8]: food chain is composed of plants, herbivores and carnivores. Here, plants, herbivores and carnivores are accordingly replaced with grass, rabbits and wolves. There forms a predator-prey relation between rabbits and grass and between wolves and rabbits.

We use a two dimensional matrix as the cellular automaton, which is composed of square cells, each cell occupied by grass, rabbits, wolves, or empty. Employing Von. Neumann neighbors, we assign that rabbits and wolves can only move

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upward, downward, leftward and rightward, and grass cannot move.

B. Initialization

First set out the probability of each species occupying the cells, and then for every square cell, we use Monte Carlo Method to simulate to determine which of the four kinds (three species and empty space) should occupy it. Initialization also includes other factors like the starvation time and the mature age for different species. Figure 2 is an example of our initialization, with white stands for empty space, green stands for grass, red stands for rabbits and black stands for wolves.

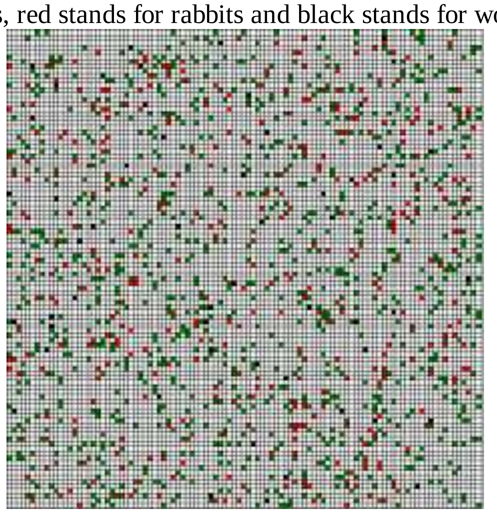

Fig. 2 Example of cellular automaton initialization

C. Running cellular automaton

Assume that cellular automaton is composed of 100*100 squares, which amounts to 10,000 in total. We make 10,000 simulations as one step so that we can make sure that every cell has one chance to evolve. Figure 3 is the result after running our cellular automaton.

To get the information about patterns in evolution, we make the cellular automaton to send out one matrix every 100 steps, 100*100. The elements in the matrix are 0, 1, 2, 3, which accordingly stand for empty space, grass, rabbits and wolves.

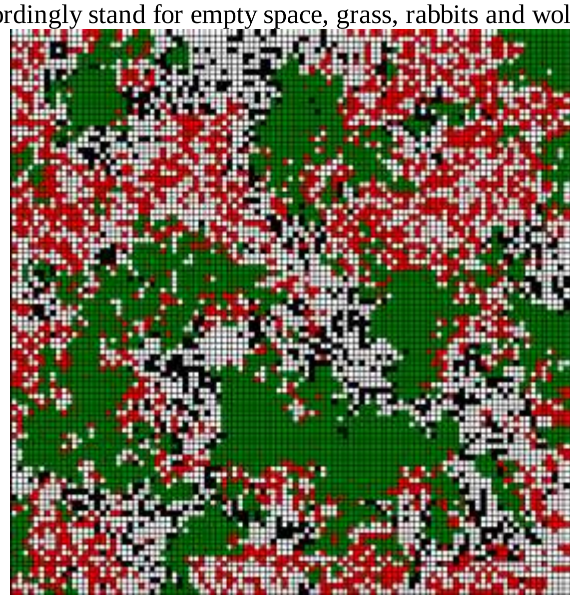

Fig. 3 Result after running cellular automaton

IV. Gathering Data And Analyzing The Evolution Of Pattern Number

We write a program to compute the number of patterns of 0, 1, 2, 3 in the matrix. Table 1 indicates the pattern number we get from 20 matrices (time series).

TABLE I
PATTERN NUMBER CHANGE FOR DIFFERENT SPECIES

	Space	Grass	Rabbits	Wolves
0	4	760	323	55
1	411	26	695	337
2	362	53	298	260
3	456	54	588	190
4	449	81	589	276
5	491	78	568	316
6	522	97	579	417
7	585	106	631	243
8	531	88	633	283
9	538	101	621	344
10	574	100	613	268
11	516	73	603	398
12	571	103	690	293
13	587	108	677	292
14	511	100	601	392
15	644	118	670	244
16	467	78	493	375
17	560	74	650	377
18	540	80	671	237
19	458	48	564	245
20	551	92	602	322

We use data from Table 1 to draw a time series curve, indicated by figure 4.

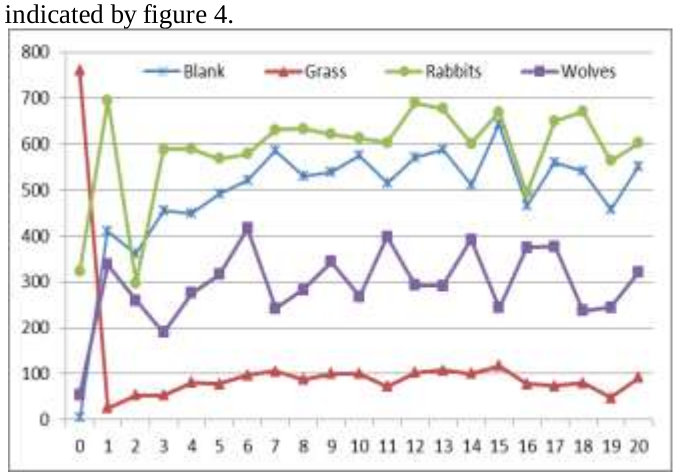

Fig. 4 Pattern number change for different species

From figure 4 we can see that the pattern number of empty space rises quickly. This is because at the beginning, the density for all three species is not big, resulting in high density for empty space, even to an extent that there is a whole piece of empty space, which we can see from figure 2. With time elapse, the density for the other three species increases and the density for empty space decreases, tearing the piece of empty space into more pieces of smaller and smaller empty space patterns. As a result, the number of patterns for empty space increases and from the 7th step, the number of patterns for empty space starts to oscillate and remains steady between 500 and 600.

The change in number of patterns for grass is exactly opposite to the change in empty space. Compared with rabbits and wolves, at initialization, the density of grass is greater, so at first the number of patterns for grass is significantly more than that of rabbits and wolves. With time elapse, the quick growth of grass makes the density of grass increases steadily and the previously dissected patterns line together, decreasing the pattern number of grass, which can be seen from figure 3.

The pattern number of rabbits at first has big shakes, but later becomes stable. The pattern number change for wolves is similar.

From figure 4 we find out that after a period of time, the pattern number of all four species discards great changes and embraces stableness. When in stableness, the number of patterns for grass is the smallest, about 100, next is for wolves, about 250, for empty space is between 500 and 600 and for rabbits is about 600.

V. Conclusion

This article uses cellular automaton to simulate the evolution of number of patterns for different species. And we find out that when the species number change has been stabilized, the pattern number will present a stable situation.

However, limited by our level, we do not consider various possibilities, this can be the breakthrough point for our future study.

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