Short Communication

Computer generation of initial spatial distribution for cell automata

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Abstract
The algorithm to generate spatial distribution patterns was developed and presented in this study. Three typical spatial distribution patterns, i.e., Poisson distribution, binomial distribution, and negative binomial distribution were included in the algorithm. The Java program was also provided. The algorithm can be used to generate initial distribution in cell automata modeling.

Keywords spatial distribution patterns; computer generation; cell automata.

1 Introduction
Spatial distribution pattern refers mainly to the two-dimensional distribution of individuals in a region. There are many types of spatial distribution patterns (Krebs, 1999; Zhang, 2007). They can be classified into three categories, namely random distribution, uniform distribution, and aggregated distribution, which can be represented by Poisson distribution, binomial distribution and negative binomial distribution, respectively. In this study I developed and presented an algorithm and Java program to generate spatial distribution patterns for cell automata uses (Qi et al., 2011).

2 Algorithms
2.1 Spatial distribution patterns
Supposedly there are three types of spatial distribution patterns, binomial distribution, Poisson distribution and negative binomial distribution (Krebs, 1999; Zhang, 2007). They represent the uniform distribution, random distribution and aggregated distribution, respectively. Recursive formulae for calculating probability of binomial distribution are:

\[ p_r = q^n, \quad r = 0; \]
\[ p_r = p(n-r+1)p_{r-1}/(r q), \quad r = 1, 2, \ldots, n, \]

where, \( p \): probability of an individual occurred in a cell, \( p = \sum f_i/(n \sum f_i) \), \( q = 1-p \), \( i = 0, 1, 2, \ldots, n; n \) is the maximum possible number of individuals in a cell, \( f_i \) is the number of cells with \( i \) individuals, \( i = 0, 1, 2, \ldots, n. \)

Recursive formulae for calculating probability of Poisson distribution are:
where, \( m \): mean of the number of individuals in a cell.

In the negative binomial distribution, the number of clusters per cell is Poisson distribution, the mean number of clusters is \( k \times \ln Q \), and the number of individuals per cluster is the logarithmic distribution. The recursive formulae are:

\[
p_r = \frac{(1 - \frac{1}{Q})^r}{r! (1(\ln Q))}, \quad r > 0,
\]

where,

\[ Q = 1 + \frac{m}{k}, \quad k = \frac{m^2}{s^2 - m}. \]

and, \( m \): mean number of individuals, \( s^2 \): variance of the number of individuals.

### 2.2 Algorithm for generation of spatial distribution patterns

Given \( p_r, r=0, 1, 2, \ldots \), are obtained from the formulae above, and there are \( N \) cells. Then the number of cells with \( r \) individuals inside the cell is \( \text{int} (p_r + a) \), \( r=0, 1, 2, \ldots, M-1 \), and:

\[
\sum \text{int}(N p_r + a) = N,
\]

where the value of \( a, 0 < a < 1 \), makes \( M \) the limited number, and \( \text{int} \) means to get integer number. Coding all cells with the ID number, 1, 2, \ldots, \( N \). Similar to the Monte Carlo simulation used by Ferrarini (2011), generate a number between 1 to \( N \) using random number generator, e.g., \( V_b \), and let \( Q_1 = V_b \). Remove \( V_b \), and re-coding the remaining \( N-1 \) numbers, and generate a number between 1 to \( N \), e.g., \( V_a \). Repeat this process until \( Q_n = V_q \).

As a result, the number of individuals in cells \( Q_1, Q_2, \ldots, \) and \( Q_{\text{int}(p_0N+a)} \) are zeros, and the number of individuals in cells \( Q_{\text{int}(p_rN+a)} \), \( i, i=1, 2, \ldots, M-1 \), where for the first summation term, \( r=0, 1, 2, \ldots, i-1 \), and for the last summation term, \( r=0, 1, 2, \ldots, i \). For negative binomial distribution, use the above algorithm in each cell. An initial spatial distribution is thus generated.

### 3 Java Implementation

The algorithm above is implemented by a Java program (based on JDK 1.1.8) (Zhang, 2011), in which seven classes and an HTML file is included (http://www.iaees.org/publications/software/index.asp). The class, BioDistriProducer, performs all calculation, while the other class is called together to complete the entire task. The user will be asked to choose the type of spatial distribution patterns, to enter the required number of spatial distribution patterns, the number of cells along the \( x \)-axis and \( y \)-axis (Fig. 1). The codes for generating the map of spatial distribution, \( \text{ran()} \), and for calculating spatial distribution, \( \text{subpr()} \), are listed as follows:

```java
public int[] ran() {
    ep=0.5;
    int s2;
    s2=(int)Math.round(p[0]*na+ep);
    r=1;
    s2+=subpr();
    while (s2<na) {
        if (s2<na) {r++;
            if (r=n) (ep)=0.5;
    }
```
Further, a window will pop up to wait for entering parameters. Enter the mean number of individuals in a
cell if Poisson distribution pattern was chosen. If binomial distribution pattern was chosen, enter the
probability of an individual occurred in a cell, and the maximum possible number of individuals in a cell. For
negative binomial distribution, enter the mean number of individuals in a cell and its variance.
4 Application

Suppose the cell automata have 100 (10×10) cells. The mean number of individuals is 100 for Poisson distribution and mean number of individuals is 200 and variance is 20000 for negative binomial distribution (Fig. 2). A Poisson distribution pattern and a negative binomial distribution pattern, generated by SpatDistriGen, are as follows (and Fig. 2):

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Fig. 2 Graphic output of initial spatial distribution.
The aggregation index, \( m^*/m \), of Poisson distribution above is 1.009 and of negative binomial distribution is 1.3437. Based on the criteria for aggregation determination, the Poisson and negative binomial distributions above are random and aggregated distributions respectively, which is exactly correct.

References
Zhang WJ. 2007. Methodology on Ecology Research. Sun Yat-sen University, Guangzhou, China