The Significance of Initial Conditions in Simulations

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Abstract

Although initial conditions often significantly affect simulation results, little attention has been paid to test model sensitivity to them. A visual demonstration of the significance of initial conditions using a simplified tissue-growth model may bring overdue attention to this common omission.

Introduction

It is perhaps no surprise to any students of simulations that, given the same set of model specifications, simulation results differ greatly depending on initial conditions. In a thought-provoking article, Maruyama (1963) used this simple observation to explain why in the embryo of certain species that when the part which would become an eye is transplanted at an appropriate stage of the embryonic development into the part which would become skin, the eye-tissue becomes skin. While the would-be eye tissue may have its own set of inherent development potentials, its eventual form is determined by its interactions with its surroundings. In other words, because initial conditions describe the surroundings under which the model behavioral rules operate, they channel the interactions between model components towards a certain deterministic result. When initial conditions differ, different results ensue, even though the model behavioral rules are the same.

The purpose of this paper is to animate this tissue-growth process so that students can play with different initial conditions online to see what differences they make in the shape of the resulting tissues.

Tissue-growth Model

Maruyama's simple tissue-growth model is as follows:

Assumptions:

- Two-dimensional space consisting of 21 by 21 (i.e., 441) squares of equal size.
- An organism consisting of 4 types of cells: green, red, yellow, and blue.
- A cell is represented by one square.
- Each type of cell reproduces cells of the same type to build a tissue.
- A tissue has at least two cells.
- Tissues grow in a two-dimensional array of squares.
- The initial distribution of 4 types of tissues is represented by colored squares, with the end cells marked by +.

Cell growth rules:

1. No cells die once reproduced.
2. Both ends of a tissue grow whenever possible, by reproducing one cell per unit time in a vacant contiguous square. If there is no vacant contiguous square at either end, that end stops growing. If there is more than one vacant contiguous square at either end, the direction of the growth is governed by the preferential order given by Rules 3, 4, and 5.
3. If, along the straight line defined by the end cell and the penultimate cell (next to the end cell) there are less than or equal to three cells of the same type (but may be of different tissues) consecutively, the preferred direction is along the same straight line. If that direction is blocked, follow Rule 5.
4. If, along the straight line defined by the end cell and the penultimate cell, there are more than or equal to four cells of the same type (but may be of different tissues) consecutively, the preferred direction of the growth is a left turn. If a left turn is impossible, make a right turn.
5. If, when a straight growth is preferred, the straight growth is impossible because the square ahead is already occupied, do the following: If the square to which the straight growth would take place is filled with a cell of the same type as the growing tissue, make a left turn. If the square ahead is filled with a cell whose type is different from that of the growing tissue, make a right turn.
6. The growth of the four types of tissues is time-wise out of phase with each other: green first, red second, yellow third and blue last within a cycle of one unit time.

Initial Configurations for Tissue-growth Simulations

Six initial configurations of seed cells are listed as examples of possible arrangements that best demonstrate the effect of initial configurations on resulting tissue structures. You can see these initial configurations online at: [Tissue Growth Game](#).

The resulting complexity of the tissues is gauged by the number of squares occupied by cells on the 21 × 21 matrix at the end of each simulation run. Six initial configurations (V1 to V6) have been preset for demonstration purpose.

Readers can create new initial configurations for other test runs by simply click-dropping the initial cells to the desired locations.

Maximum-growth and Minimum-growth Initial Configurations

The sample initial configurations and their resulting tissue growths allow us to make the following observations:

- The same cell-growth rules can lead to very different simulation results depending on the initial configurations.
- Different initial configurations lead to very different simulation results because some initial configurations allow more interactions with neighboring tissues and other initial configurations lead to little or no interactions.
- The initial cells of those initial configurations that lead to more interactions among tissue types are closer to each other and have more room to grow on all 4 sides (see Initial Configuration – V6).
- The initial cells of those initial configurations that lead to little or no interactions among tissue types are far away from each other and located near the boundary on two sides (see Initial Configuration – V2).
- Even minor differences in initial configurations can lead to significantly different simulation results.
- Comparing only the end results, we are hard put to conclude that they result from the same set of cell-growth rules.

Cautionary Note for Students of Simulations

Many published simulations do not bother to test the sensitivity of simulation results to different initial conditions. As such, these simulation results are sufficiently but not necessarily valid. This exercise shows that it is good practice to test the sensitivity of simulation models to not only different parameter values governing the behavioral rules but also to different initial conditions under which the behavioral rules operate.

Implications for Social Simulations

The simple model of tissue growth might seem to be far removed from social simulations. But the lessons on the significance of initial conditions are easily applicable to social simulations. For example, the same behavioral rules governing tissue growth could just as easily be applied to the expansion of human settlements among different ethnic groups. Specifically, in some initial configurations, the ethnic groups are interspersed with one another. In other initial configurations, the ethnic groups are segregated into their own cocoons.

References

MARUYAMA, M (1963) The Second Cybernetics. *American Scientist*, vol. 51, 1963: 164-179.