Cellular Evolutionary Algorithm

Sean Donaldson

Introduction

The Game of Life provides a simple example of cellular automata, or cellular simulation with computational methods. The simulation described below loosely follows the Moore Neighborhood configuration that defines The Game of Life (1). Unlike The Game of Life, each cell reproduces, and dies, according to the amount of food that each cell consumes. Each cell has a set of attributes that determines its ability to survive, and its ability to reproduce. Every set of attributes that belong to each cell has a 3% chance of mutation upon asexual reproduction. Thus, resulting in a new generation of cells with slightly different attributes. These cells are constrained to a defined two dimensional space and must survive from the food within this space.

Goals

There are two goals of this simulation.

- To observe the behavior of the cellular colony population with respect to time.
- To observe the evolution of the cellular generations with respect to time.

Cell Attributes & Mutation

Each cell has its own set of attributes.

- Food consumed (c), the total amount of energy that the cell has stored.
- Food rate (r), the rate that the cell burns its stored energy per time step.
- Food quality (q), the amount of energy gained upon consuming one unit of food.
- Reproduction limit (l), the minimum amount of energy that the cell must have in order to reproduce.
- Birth penalty (b), a factor which determines how much energy is consumed upon reproduction.

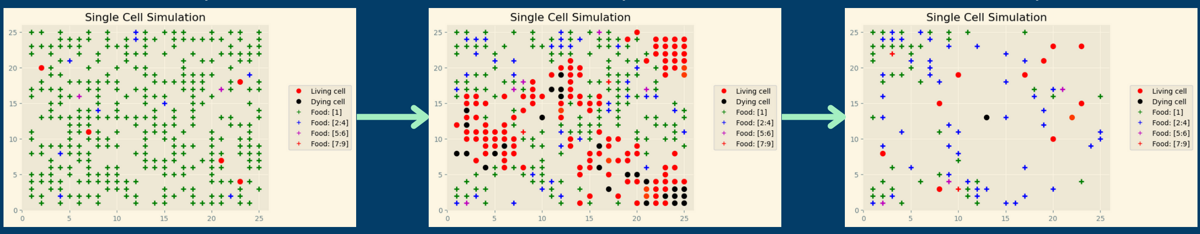
With the exception of the food consumed attribute, the values are all mutated with the following equation:

$$V = P + \alpha$$

Where V is the resulting attribute value of the new cell. P is the parent cells' attribute value, and α is a randomly selected value that may be -1, 0, or 1.

The Colony Simulation

time step = 1 time step = 47 time step = 80



Cell Movement

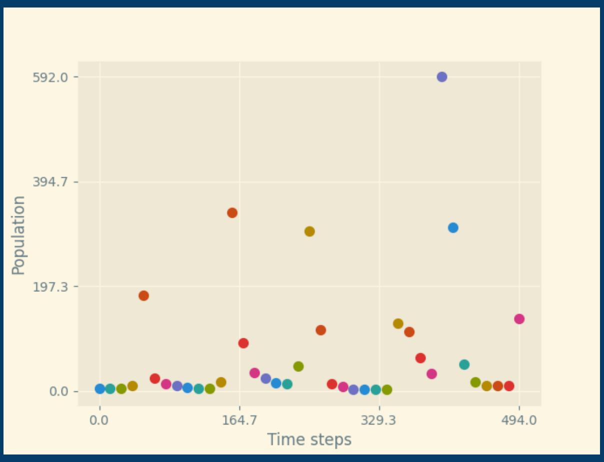
Cell movement is defined by three overall steps.

- If the cell is currently on an index with food, the cell stays put and consumes the food.
- If there is no food on the cells' index, the cell moves to the index with the highest amount of food within 1 index away.
- If there is no food nearby the cell, the cell randomly walks until food is found, or it dies.

Results

The results of the simulation show that the population is in a repetitive cycle of explosion and implosion. For shorter simulations, less than 5000 time steps, the populations can explode to values around 300 to 600 while quickly dropping to population values below 20 as shown in **Figure 1**. For simulations that approach ten thousand time steps or longer, not shown, the population begins to approach a sinusoidal behavior as the colony begins to evolve to attributes that provide a more stable population.

Figure 1



The evolution of the cells throughout the simulation shows an example of survival of the fittest. Whereas the initial generation eventually dies off, subsequent generations begin to take over the space. Furthermore, some mutated generations can be seen to go extinct within a short period of time, as shown in Figure 2, until another mutated generation takes its place. For the simulation shown, the attributes of generations 0 to 2 are:

Generation x: (r, q, l, b)
Generation 0: (2, 5, 100, 2)
Generation 1: (1, 5, 99, 1)
Generation 2: (1, 4, 99, 2)

Spatial Matrix

The cell colony is constrained to a two dimension plane.

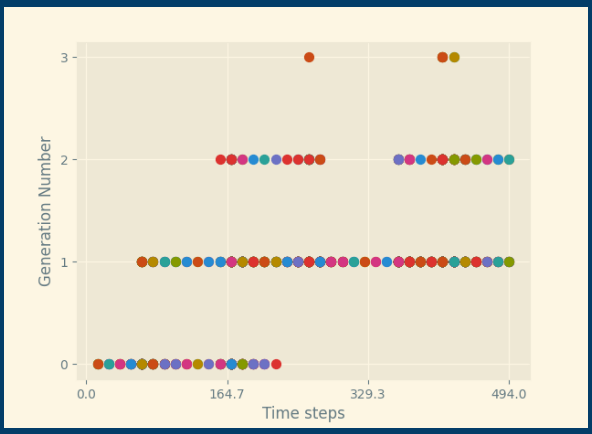
- The 2D plane is defined as a 25 by 25 matrix

These attributes are beginning to show the evolution to a more stable cell. To explain further, generation one can be seen to have the strongest survival in **Figure** 2, but it is likely that this generation would quickly go extinct. This is because generation one, has a birth penalty which severely punishes every generation one member for reproduction. To show why, the birth penalty is used in the following equation:

$$cf = ci - ci / b$$

Where cf is the resulting food consumed value (c), and ci is the initial food consumed value (c). Thus, is can be shown that the food consumed value for every generation one member goes to zero upon reproduction. This penalty results in a colony which has reproduction, and thus survival of the species, as a quality which punishes the species rather than favors it.

Figure 2



Conclusions

- Populations confined to a space with a limited amount of food will lead to rapid oscillations in the population. However, if mutation results in favorable characteristics, the population can lead to a more stable colony.
- Survival of the fittest shows that generational evolution does not always trend towards favorable attributes for the cells. This unfavorable mutation can be ,temporarily, irrelevant depending on the attributes of the total population.

(1) Hoekstra, Alfons G., Et al. "Simulating Complex Systems by Cellular Automata." Springer (2010).