Lab G7 - Natural Selection

Shaoyong Guo
Politecnico di Torino
s296966
s296966@studenti.polito.it

I. Introduction

The simulator allows for the study of simple natural selection processes of various species in the scenarios of mobility, fight and survival. I will study the process of generation of various species and the difference between the theoretical and actual lifespan of species based on three interestingly different scenarios.

In my simulation, I set up five species ['A', 'B', 'C', 'D', 'E'] with an initial population of 10 to simulate five animal races. Each species will produce a variety of offspring over 200 years. They migrate families and generate wars with each other over the period of 200 years. I use mobility, fighting and survival models to simulate the process of natural selection and record all changes in each species every 10 years.

Finally, it is also possible to study the difference between the theoretical and actual average lifespan of all species, as well as population trends over time.

(Describe some interesting questions to address based on the above simulator. expect output results and metrics.)

II. The simulation model

A. Stochastic Elements

Initial Populations For Each Species. In the simulation, I set up five species and each species have same initial condition: 10 population. The initial conditions are such that each species has 10 individuals in the first generation, which will produce all offspring in the simulation year with the same average reproduction rate, improvement factor and improvement probability. In addition, I created "SID" as an identifier for each individual. For example, "A1243" indicates that the individual belongs to species A, is fourth generation, and is a descendant of "A124".

The Lifespan. The simulator can random generate a lifespan for every lifespan with follow formula:

$$LF(k) = \frac{1}{LF(d(k) * (1+\alpha) - LF(d(k)}, (x < probability)$$

In this case, I set an improvement probability that allows the simulator to randomly assign individuals a uniformly distributed lifetime when the random probability exceeds this probability. The alpha represent the individual could improve their lifespan. However, if a random probability do not exceed this improvement probability, the simulator will adopt a lifespan for individual with the the formula:

$$LF(k) = \frac{1}{LF(d(k)}, (x < 1 - probability)$$

Position and Region. Individuals migrate randomly in a given region during the simulation time, so I had to set a migration region for all species. In my simulation, I designed a function to generate a 20 x 20 two-dimensional grid and randomly give the initial individuals of all species a location.

The Maximum Offspring. In reality, it is improbable that an animal can produce an infinite number of descendants. Therefore, I have set a maximum of 5 offspring for each individual. The number of descendants is recorded during the simulation. Theoretically, any individual will stop producing offspring when it reaches the maximum number of descendants or dies before the end of its lifespan.

B. Input Parameters

Average Reproduction Rate.
In the input parameters, I adopted various ratios from the beta list as the average reproduction rate of the offspring, respectively. Theoretically, if the average reproduction rate is less than 1, the species will become extinct; conversely, there will be a population explosion in the future.

The Improve Factor and The Improve Probability
The improvement factor and the improvement probability determine the longevity of the offspring. In each generation, the improvement probability is a threshold for whether the next generation will live longer than the previous one, while the improvement factor determines how long the next generation can improve its lifespan.

The Dictionary for Recording Data. In order to collect all types of data, I set up some dictionaries in the simulation.

I set up a final species dictionary to record all species and individual categories, for instances:

$$\{sid : individual\}$$

It can quickly access any individual information by using "sid". The final position dic record all position information of individuals, such as :

$$\{position : [sid]\}$$

This displays how many individuals are in a specific location. And the time population dict record all account of number various species over time:

$$\{time : [sid]\}$$

It displays the amount of individuals of each species at time T.

Algorithm 1 An algorithm for Natual Selection

Require: $Time \leq SimulationYears$
Ensure: $Individuals$
$Species\_Dictonary$
$New\_position \leftarrow Individual.position$
$\{position : sid\} \leftarrow All\ position$
$Check\ amount\ of\ species\ at\ a\ position$
while $amount \geq 2$ **do**
$Fighting\ Model$
$Loser = np\ .random\ .\ randint(0\ ,len(sid\_list))$
$remove\ losers\ form\ Species\_Dictonary$
end while
$update\ Species\_Dictonary$
$update\ Posiotion\_Dictonary$
$update\ Population\_Dictonary$

C. Algorithm and Data Structure

The Class of Children. In simulation, I designed a class for an individual which includes parent ID, child ID, birth time, generation, theoretical lifespan, number of descendants and current position. When a individual is born, their initial position is inherited from their parents.

The Process of Natural Selection Model. During the simulation, I adopted three types of dictionaries to record all the information about each individual at different times. To begin with, I defined an individual class, which mainly contains the ID, lifespan, and position of the individual. An individual instance can be created by providing its ID and current time. The initial instance of each species has 10 individuals. Over time, individuals can continue to produce descendants, change their position through the movement model, and generate wars through the fight model.

$$species\ dictionary = \{ID : INSTANCE\}$$

$$position\ dictionary = \{(x, y) : [ID_1, ID_2, ...]\}$$

$$population\ dictionary = \{species : population\}$$

The species dictionary records all IDs and instances over time. The position dictionary records the positions and IDs of individuals that are present at that position at a particular point in time. it is always updated with all contents at each point in time. The population dictionary will record the population size of each species at different times.

D. Models

Mobility model. Each individual has a 2D position and can move 1 random grid at a time in 4 directions (up, down, left, right). They cannot cross boundaries, but can stay in their current position or move in other directions. During the movement, they will encounter each other at some time point.

Fight model. When individuals of different species meet, they create a war to determine who survives. I set a rule for the war that when different species meet, the simulator randomly selects some of the individuals to survive. Losers will be recorded in the losers list and removed from the final species dictionary. The remaining individuals will move on and produce the next generation.

Survivabilty model. Individuals fail to survive in one of two ways. They lose the war when they encounter others during their movement, and their lifespan has already ended. When they die, the ID is removed from the final species dictionary.

III. Results

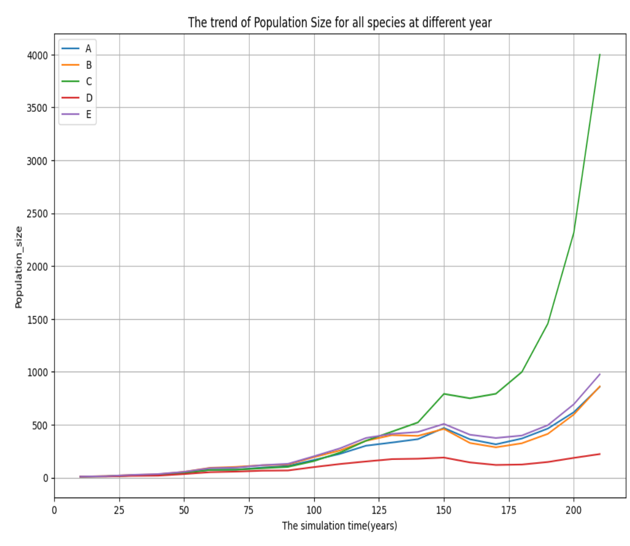

Fig. 1. Actual population at different periods.

Fig. 2. Species Migration Over Time

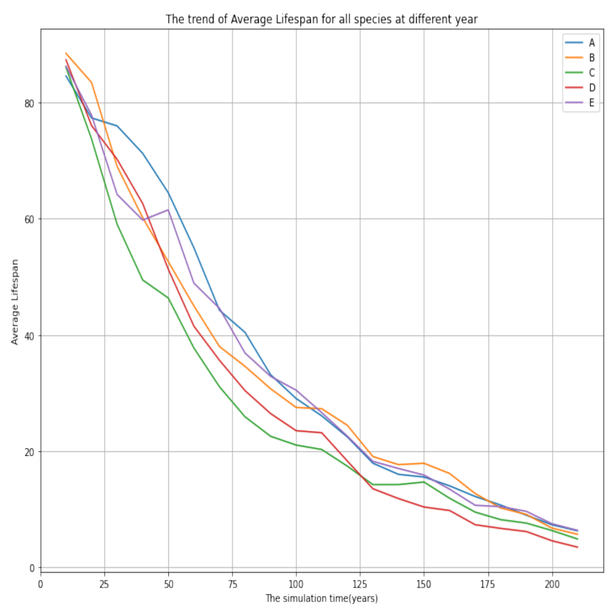

Fig. 3. Average Lifespan Over Time

A. Output Metrics

Population Size Over Time. As shown in Fig. 1, with the same initial conditions of population size and reproduction rate, the population sizes of all species fluctuated and increased over time, while the differences in population sizes between species expanded.

Migration of species and actual population growth. There is an interesting phenomenon that each species always appears with high probability in the same area at any point of time. The results of Fig. 2 can show this idea directly. In animal societies it can always take place and gradually organise itself into different organisations.

Average Lifespan over species. In Fig. 3, surprisingly, the average lifespan of species decreases gradually. The reason for this is almost related to the battle strategy in the battle mode.

IV. Conclusion

For a single species, reproduction rate is the most critical factor in determining whether it will become extinct. If the average reproduction rate is less than 1, they will almost become extinct; conversely, they will almost experience a population explosion after many generations.

For a group of species, individuals migrate randomly in different directions within a given area. When individuals of different species encounter each other, they may fight to determine who survives. In reality, individuals migrate in random directions and over small distances and gradually form an organisation within their territory. However, this territory is highly correlated with the area where their ancestors first stayed. On the other hand, when individuals "invade" other territories, it is almost impossible for them to survive, or for their descendants to survive in other territories. In fact, species with larger populations are always in an advantageous position to compete in an area; they have more opportunities to reproduce more descendants, and the descendants live longer.