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COLLEGE OF COMPUTER STUDIES
DEPARTMENT OF COMPUTER SCIENCE

Natural Selection: A Simulation

A Project presented to the
Department of Computer Science
College of Computer Studies

In partial fulfillment of the requirements
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for the degree of Bachelor of Science in Computer Science

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1 Overview

1.1 Purpose

Natural selection is a naturally existing phenomenon in which the populations of organisms change and adapt to their given environment. This process is a key component of evolution and how a species change throughout the generations.

The purpose of this model is to give a grasp of understanding on how natural selection works and how the environment/ ecosystem can affect the entirety of a species, its population, and its traits. This is a simple 2D model that is designed mostly for students or people who are simply just curious about the study of evolution.

1.2 Entities, State Variables and Scales

This model consists of only one agent: the turtles. In this model the turtles are the main subject for the display of natural selection. Other entities include the sea floor and the sea grass. The sea floor is a 40 x 40 grid space (-20 to 20 for x and y) where the turtles roam and swim freely. Occasionally, throughout the sea floor, sea grass can be grown. This sea grass is what the turtles would eat in order to survive or reproduce. Sea grass, however, is not the only entity that a turtle can eat. Turtles can also eat and cannibalize other turtles as long as they are bigger than their prey.

Initially, before this model starts the simulation, some variables can be adjusted to specify to a situation. First the 'population', this is the initial number of turtles that are created and spread throughout the map. Turtles also have the variable 'energy'. This variable is what determines the survival of a turtle. Next, for the growth of sea grass across the sea floor, we have the 'max-food' variable. This variable determines the maximum number of grasses grown that should be available through the whole sea floor. This variable is only a scale from zero (0) to one (1) that determines the percentage of the area allowed for sea grass to grow. Another variable for the growth of the sea grass is the 'grow_rate'. This variable is the rate of growth of the sea grass in the model. Finally, the initial traits of the turtle: the speed, vision, and size. Speed is the distance a turtle can travel in a single tick, vision is the radius in which the turtle can see in a 180 degree cone, and size is how big the turtle is.

1.3 Process Overview and Scheduling

This model provides a simple set of rules in which it follows. To start, the map is created by adding the sea floor. Then, in the sea floor, sea grass is grown depending on the growth rate given. A number of turtles are then created throughout the map. This is the starting setup for this model.

The entire map is covered in seafloor. In this seafloor, sea grass can grow depending on chance. Every tick, a single patch has a chance of growing a grass patch. The growth rate can be set when setting up this simulation and is only limited to be a maximum of 10% chance per patch per tick. Whenever a turtle passes trough this patch, the turtle consumes the grass and returns it back to be a seafloor.

For the turtles, there are quite a bit more rules than the patches. First, the turtles move across the map at random. Moving costs energy that is dependent on the turtle's size, speed, and vision. To increase a turtle's energy, the turtle must eat grass or another turtle that is at least 20% smaller than them. As for movement, the turtles would move randomly throughout the space until another turtle or a patch of grass enters its field of view. If a grass patch enters the view of a turtle, then it will recognize it as food, and move towards it. If another turtle enters its vision, it will first determine if it is a predator or a prey (depending on size), then would either flee or move towards it. In the case that multiple entities enter its vision, turtles would prioritize fleeing from a predator. Otherwise, if there are no predators, then the turtle finds the nearest source of food in its vision and move towards it.

Throughout the movement, if a turtle's energy runs out, then the turtle dies. However, I the turtle's energy reaches the maximum amount, then that turtle would reproduce, creating another turtle with traits very closely related to its parent. The value of these traits (speed, vision, and size) would be mutated to be increased or decreased by a maximum of 1.

To explain the entire process, start with Initializing the map, then:

1. Grow the sea grass
2. Let the turtles move (and eat)
3. Turtles will reproduce
4. Kill turtles (if energy = 0)
5. Repeat

2 Design Concepts

2.1 Basic Principles

For this model, we will be exploring natural selection and the theory of evolution. Natural selection suggests 'Survival of the Fittest', and in this model, being 'fit' means being able to find food efficiently as well as being able to avoid predators.

In Darwin's theory of evolution by natural selection, it entails three important elements: variation, reproduction, and heritability. In this model, turtles have three traits: speed, vision, and size. Each turtle varies with these traits with some being faster, some perceiving their surroundings better, and some being bigger. These traits give the turtles advantage or disadvantage as they struggle for survival.

2.2 Emergence

The intention of this model is to observe the changes in the traits of the agents. The change of the speed, vision, and size of these turtles are emerged from the environment that they live in and the other turtles that they compete with.

2.3 Adaptation

The turtles each have the traits: speed, vision, and size. Each of these traits can have a value from one (1) to ten (10). Whenever a turtle reproduces, they create another turtle whose traits are largely similar to their own. Throughout generations of turtles, the variation and the average of these traits are observed.

2.4 Objectives

For an individual turtle, its objective is to survive as long as possible by finding more food and avoiding predators. This is where its adaptive traits help. These adaptive traits provide the turtles advantages in surviving the environment. However, these traits would come at a cost of using up more energy. The changes/ adaptations made over time would be the result of natural selection.

2.5 Learning

In this model, adaptive traits change based on the consequences of the environment instead of the consequences of previous experiences. Thus, learning is not represented in his model.

2.6 Prediction

Like learning, prediction is also not represented in this model. The adaptive traits do not change based on future estimations but through mutations.

2.7 Sensing

All turtles are given a 'vision' trait. This determines the radius of what they can see within a cone of 180 degrees. Through this trait, turtles can sense if a predator, prey, or a patch of grass is nearby. The turtle would then act accordingly depending on what was seen; flee if they saw a predator and move towards if they see a prey or a patch of grass.

2.8 Interaction

For the turtles and the grass patches, the turtle interacts with it by eating those patches and gaining energy from it. For turtles interacting against other turtles, one turtle would be the prey and the other would be the predator. Prey will always try to run away from the predator, but the predator would only eat the prey if it were the closest food source available, otherwise, the predator eat whatever is nearest.

2.9 Stochasticity

In terms of stochasticity, it is used in the growth of the grass patches and the adaptations/ changes during reproduction. For the growth of the grass, every seafloor patch has a chance to grow a grass patch every tick. This chance is: growth_rate / 1000. The 'growth_rate' variable is set up during the initialization phase of the model. For the adaptation, the turtle's traits (speed, vision, and size) can each vary from 1 to 10. During reproduction, the parent turtle replicates and creates a child turtle. The child turtle would have the traits of the parent turtle, but the value in these traits is increased by a random number from -1 to 1.

2.10 Collectives

While turtles can have similar traits, they do not form a collective. They act only as an individual. In this model, there are no collectives.

2.11 Observation

The main result of interest of this model is how the population adapts/ changes based on the environment. These patterns show the changes and the adaptations of the turtles as they interact with their environment, and other turtles. However, it is up to the observer to interpret the data and analyze how or why it resulted in that way.

3 Details

3.1 Initialization

Before starting the model, there are a few variables that require initialization.

- population – the initial population of the turtles
- max-food – the maximum amount of food that spawns in the map
- growth_int – the rate of growth of the grass patch per tick in integer. Added together with decimal
- growth_dec – the rate of growth of the grass patch per tick in decimal. Added together with integer
- initial-size – the initial size of the turtles
- initial-speed – the initial speed of the turtles
- initial-vision – the initial vision of the turtles

3.2 Input Data

No external models or exogenous input data is used in this model

3.3 Submodels

For this model only one submodel is used. Every movement of a turtle, it costs energy. The amount of this energy is dependent on the three adaptive traits that the turtles have: speed, vision, and size.

To start, I attempted to use the formula for kinetic energy ($K = \frac{1}{2} mV^2$). Which resulted to:

energy cost = ½ * size * speed^2

This result is what I based my formula for the energy cost per tick. For the size, an exponent of 3 is added to make it similar to a volume. And because vision is part of the turtle's adaptive traits, it is inserted into the formula. The result would be:

energy cost = ½ * ((size^3 * speed^2) + vision)

However, this would be too big for something that is executed every tick, so it became:

energy cost = 1/10 * ((size^3 * speed^2) + vision)

4 Observations and Results

Through different environments, the traits of the turtles can be observed to be undergoing change and adaptation. For my personal observations, the adaptation and the process of natural selection is sometimes unpredictable. Through observation, it is shown which trait the turtles value more depending on the environment that they are in. Overall, with the changes in the traits throughout the population, the process of natural selection was undergone.

References

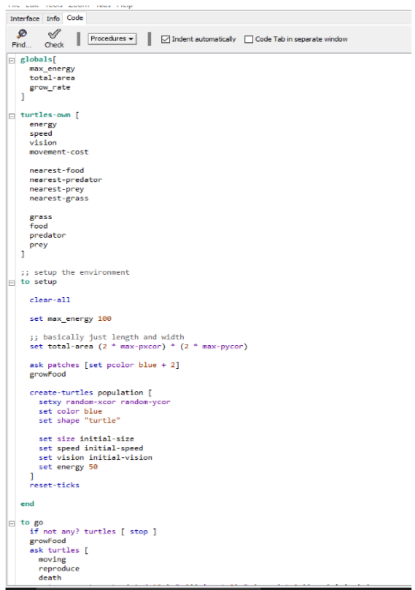
C. Cunningham. 2020. *Survival of the fittest*. *Encyclopedia Britannica*, 11 Feb. 2020, https://www.britannica.com/science/survival-of-the-fittest.

National Geographic Society. 2019. *Natural Selection*. https://www.nationalgeographic.org/encyclopedia/natural-selection.

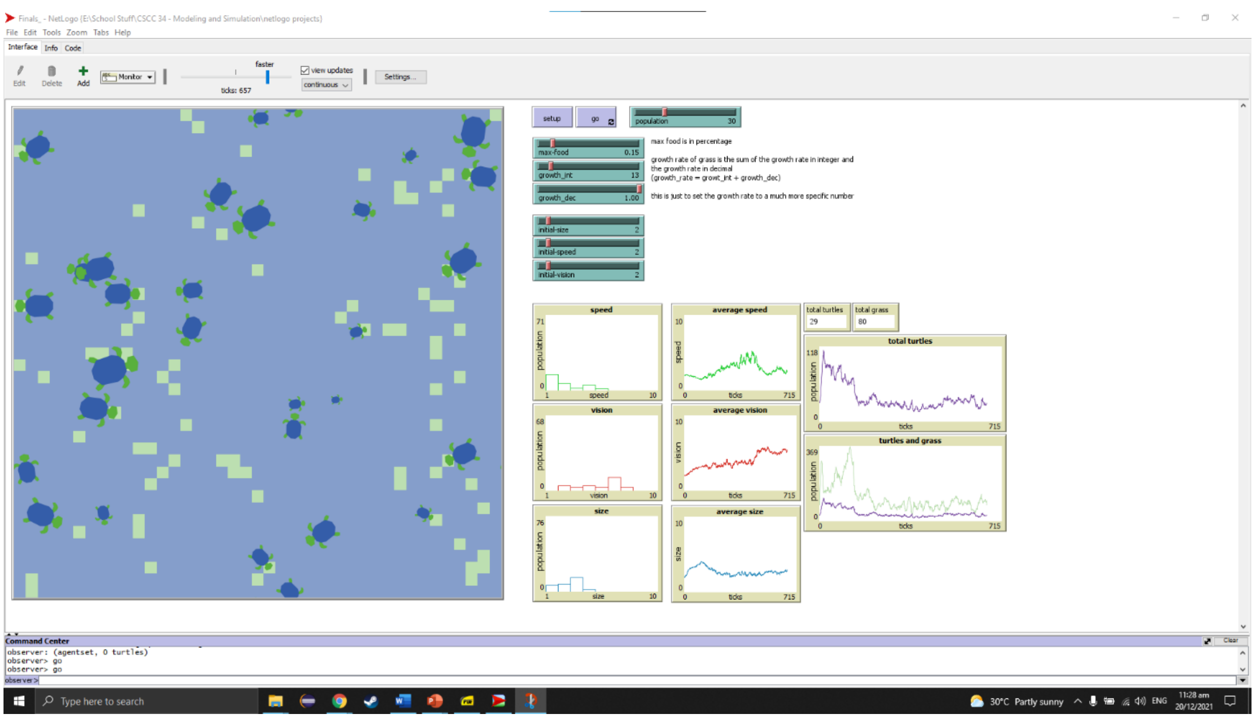
Primer. 2018. *Simulating Natural Selection*. https://www.youtube.com/watch?v=0ZGbIKd0XrM.

Appendices

Screenshots



(The code in netlogo)



(The simulation layout)