Modeling Natural Selection with NetLogo

Daniel Cohen-Cobos

Department of Computer Science, The College of Wooster

April 8, 2022

Contents

Abstract

In this paper we looked into simulating natural selection using an agent-based computer simulation, monitoring their traits and their evolution across generations. The simulation was written in NetLogo to model an environment in which the simulated species sought food to survive each iteration. If the agent collected enough food it reproduced having a child that could mutate its set of traits. It could change its average velocity, awareness of its surroundings, orientation, or violence towards other agents, potentially gaining the ability to steal food from its own kind for survival.

[primary findings]

[results and conclusion]

1 Introduction

1.1 What is Natural Selection?

Charles Darwin introduced the concept of natural selection in his book titled *On the Origin of Species* in 1859. This book contradicted what he denoted as *artificial selection* which had been imposed in the Catholic Bible, where each species had been specifically designed and had always remained constant in their respective characteristics. He defined natural selection as the ability of species to adapt to their environment [1]. Species change to adjust to their surroundings and improve their chance of survival.

1.2 How does it work?

In a nutshell, species across generations mutate to adapt to their surroundings. *Distinct species of organisms apply themselves to different ecological tasks using their appropriate sets of tools* [2]. They mutate slowly and those who can manage to adapt better will ~~be the ones to~~ survive, and then reproduce repeating the cycle. Those who have unsuccessful mutations will be more likely to die and therefore will not spread the wrong mutation to the next generations.

In real life, noticeable traits can be seen by comparing species thousands of years apart. After various successful mutations, different variations of the same initial species can coexist together. *While many of these forms differ in subtle ways, most can be readily recognized and categorized as types or species quite distinct from others* [2]. This idea was tested in this study, where in the first iteration, all individuals had the same traits, and by the end of the simulation, there were almost no two identical individuals.

2 Procedure

2.1 Tools

In this study, we used agent-based programming to model natural selection. This type of programming allows simulating various instances of an agent and its interaction with its environment and other agents. In our case, this described agent was the species to examine, and the environment is the map on which the agents will be simulated in. Agent-based programming allows agent-agent and agent-environment interaction, which was the main reason why this type of simulation was chosen.

The agent-based programming language used in this study was NetLogo, because of its easy use, efficiency, and its versatility [3]. NetLogo creates a 2-dimensional output to view the environment, the agents, and every interaction that occurs in each iteration. It can also output graphs to monitor parameters within the simulation, or create variables such as mean, the highest number of certain variables, or other parameters to use for a better analysis of the evolution.

2.2 Model Design

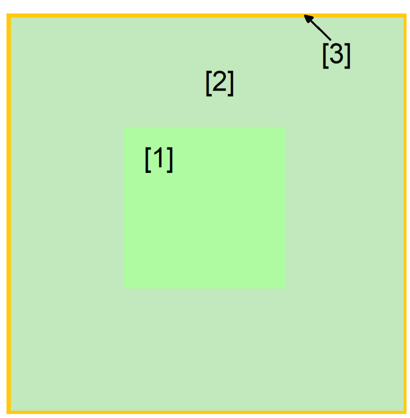

Figure 1: Model's Environment divided into three zones. [1] home zone, [2] empty zone, and [3] food zone.

The model was based on [4, 5], and consists of a 2D plane on which the species lies. The plane has the shape of a square and is composed of three zones, as seen in Fig 1. The **home zone** is where the species start and end after each iteration; the **empty zone** is where the species start moving through when the iteration starts, on their way to the **food zone**, where food is randomly placed.

2.2.1 Food Mechanics

Food serves as a way of survival and reproduction. If an individual collects one unit of food and manages to bring it back home before the iteration finishes, It will survive that iteration. If it manages to collect two units of food and bring both of them back home, it will not only survive but also reproduce, creating a new instance of itself with a chance of a slight modification to its parent´s traits.

2.2.2 Species

The Species start in the home zone and will start moving as soon as the iteration starts. They each have an orientation parameter that will be used to determine how they move towards their next objective. The species first goes through a seeking phase where they will go towards the middle of the map to collect their item of food which will allow them to survive that iteration. Once it comes close enough to a food unit, the individual will collect that item and carry it as long as it has room to store it. Once they collect their food, they will start their second phase where they will move in the opposite direction to the middle, so they can return to the home zone. On their way back, they may collect their second food item which will allow them to reproduce, but they may not collect a third food item. If the individual loses their food item (explained in the trait section), they will return to their first phase and switch directions towards the middle. The species are constantly moving until they reach the home zone after collecting their item(s).

When they reproduce, the child will receive the same trait parameter as its parent. The simulation will have an evolution parameter that will determine the chance of the child to have a mild modification to those trait parameters. If there is a modification, those modifications will also be random and distributed across the different trait parameters.

2.3 Traits

2.3.1 Speed

The speed trait makes the species run faster in one of the phases, but as a consequence to conserve energy, they go slower in their other phase. This should be very beneficial to ensure they either collect food faster before it gets collected or to make sure the food gets home safer. This trait has those two possibilities, in which the speed trait parameter can be positive for a faster first phase, or negative for a faster second phase.

2.3.2 Awareness

?

The awareness trait makes the required distance to collect food wider, which allows the agent to find food faster and return home sooner. The downside of this trait is that their orientation worsens with this trait. The metaphor behind this idea is that a high awareness implies that the agent moves around more and gets "distracted" easier by what he sees around him.

2.3.3 Orientation

Opposite of awareness, the orientation trait makes the agent ensure the travel between phases a straighter line for a faster collection and return. As a consequence of the trait, the agent moves slower overall, since it requires more energy to orientate. A way to think about this is that they won't take the wrong route by double-checking where they are going.

2.3.4 Violence

As the last trait, the violence trait parameter enables the agent-agent interaction by allowing agents to steal food from one another. When they interact with each other, each agent will have a probability of stealing a food unit from the other agent (if he has at least one), based on its violence parameter. The higher the violence, the more likely it is that an agent completes the robbery. If they both have a violence trait parameter, there is a chance they fight for the food where they will exchange the unit until one of them fails to steal from the other. As a consequence, they only steal for survival, which means that they cannot steal food if they already have a food item. This helps their survival but limits them to reproduce by stealing. Also, they have worse orientation, to ensure they move more on their phases and encounter agents easier.

3 Results and Analysis

4 Conclusion

5 Acknowledgement

I'd like to thank The College of Wooster Computer Science Department for the tools needed for this report, Including Dr. Guarnera, the Teacher Assistants Pavithra Reddy, and Brandon Charles for helping me with my setup and procedure.

References

[1] N. Geographic, "Natural selection," 2019. Accessed on April 4th 2022, `https://www.nationalgeographic.org/encyclopedia/natural-selection/#:~:text=English%20naturalist%20Charles%20Darwin%20developed,On%20the%20Origin%20of%20Species.`

[2] T. L. Vincent and J. S. Brown, *Evolutionary game theory, natural selection, and Darwinian dynamics*. Cambridge University Press, 2005.

[3] U. Wilensky and W. Rand, *An introduction to agent-based modeling: modeling natural, social, and engineered complex systems with NetLogo*. Mit Press, 2015.

[4] Primer, "Simulating natural selection," 2018. Accessed on February 24th 2022, `https://www.youtube.com/watch?v=0ZGbIKd0XrM`.

[5] B. Glymour, "Wayward modeling: population genetics and natural selection," *Philosophy of Science*, vol. 73, no. 4, pp. 369–389, 2006.

[6] A. Kleinman, "The basic science and mathematics of random mutation and natural selection," *Statistics in Medicine*, vol. 33, no. 29, pp. 5074–5080, 2014.

Appendix

This study was inspired by Primer's Youtube series on natural selection and trait evolution [4]