Evolutionary Models with a Large Number of Genes

Mher Saribekyan, Suren Hakobyan, Davit Badalyan
Instructor: Varazdat Stepanyan

American University of Armenia

November 2024

Contents

1 Introduction

Have you ever asked yourself how humanity has reached its current state of being? Have you ever wondered how some species (including humans) survived throughout centuries of changing environment, while others went extinct? The answer to these and many other questions lie in the broad study of evolution.

According to Cambridge Dictionary, evolution is defined as *"the way in which living things change and develop over millions of years."* Living things inevitably change over time due to multiple reasons. For example, a long-term food shortage caused by the change in the environment can force a given species to eat less, which over time will affect the next generations of the same species. The new generations might become more and more resistant to starvation and require less nutrition to survive. During this transition, many representatives of the species might die, and in some cases the species might fail to adapt and go extinct. However, if it **evolves** successfully, then the species will continue it's existence in the new environment, which might once again change in the future.

A more scientific definition to the term evolution was given by Douglas Futuyma in his popular textbook.

> [biological evolution] is change in the properties of groups of organisms over the course of generations... it embraces everything from slight changes in the proportions of different forms of a gene within a population to the alterations that led from the earliest organism to dinosaurs, bees, oaks, and humans.

Evolution can occur by different means, such as natural selection, genetic drift, mutation, migration and so on. This report will simulate the process of species evolving over time by adapting to their environment through mutations and natural selection. It will explore scenarios with different starting conditions, where diverse creatures with unique genes inhabit varying environments. The study will examine how these genes mutate over time and determine which mutations dominate in each specific setting.

2 Methods

2.0.1 Creature

A creature is defined with its genome, position and energy. The genome consists of 5 genes that represent certain characteristics of that creature. The position shows the creature's position in the grid and the energy shows its energy level.

2.0.2 Food

Food are randomly generated when a simulation is initiated and randomly spawns in each timestep, but with a predefined limit.

2.0.3 Energy

A creature starts with predefined base energy level, and dies when the energy level reaches 0. The creatures gains energy by consuming food or winning an attack against another creature, and loses energy when moving.

2.0.4 Attack

A creature has a gene for its level of aggression, which shows how likely it is to initiate an attack. The winner is determined by the strength gene. The winner gains energy, while the loser dies.

2.0.5 Reproduction and Mutations

If a creature gains energy with a certain ratio of its maxmimum energy, it reproduces and gives 1 offspring, and loses a certain ratio of its energy. The offspring is spawned in an adjacent positon and each gene is copied from its parent, with a certain probability for each gene to change by a value of 1.

2.1 Memory optimization

The creature is defined as an unsigned 32-bit integer, where the first 16 bits represent the genome, the next 12 bits represent its position cell and the last 4 bits represent the energy.

2.2 Energy loss

$$\text{energy loss} = \text{steps} + \left\lceil \frac{\text{eyesight}}{3} \right\rceil + \left\lfloor \frac{\text{aggression}}{5} \right\rfloor + \left\lfloor \sqrt{\text{strength}} \right\rfloor + \left\lfloor \frac{\text{stamina}}{7} + 1 \right\rfloor$$

$$\text{eyesight} \in \{0, 1, ..., 7\}$$

$$\text{aggression} \in \{0, 1, ..., 7\}$$

$$\text{strength} \in \{1, 2, ..., 16\}$$

$$\text{stamina} \in \{-7, -6, ..., 8\}$$

All these values have an effect on how much energy the creature spends. Steps are the number of steps. We have no energy loss from aggression, up until the value of 5.

Gene	Bits	Description
Speed	2	Takes values between 1 and 4, showing the Manhattan distance the creature can walk in a single timestep.
Eyesight	3	Takes values between 0 and 7, showing the Manhattan distance the creature can see.
Aggression	3	Takes values between 0 to 7, mapped to 0% - 100%, showing the probability of the creature attacking another creature in the same cell.
Strength	4	Takes values between 1 and 16, which determines the winner in a fight
Stamina	4	Takes values between -7 and 8, which is added to the base energy level, when generating the creature

Table 1: Creature characteristics and their descriptions

Speed		**Eyesight**			**Aggression**			**Strength**				**Stamina**			
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2 bits		3 bits			3 bits			4 bits				4 bit			

Figure 1: Gene storage

Position												**Energy**			
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12 bits												4 bits			

Figure 2: Position storage

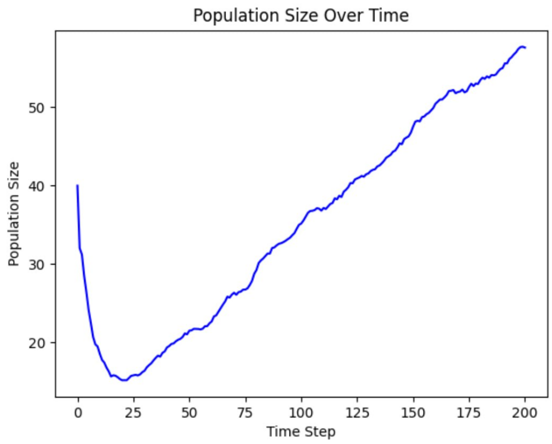
The creatures are stored in a list and are iterated over in every timestep.

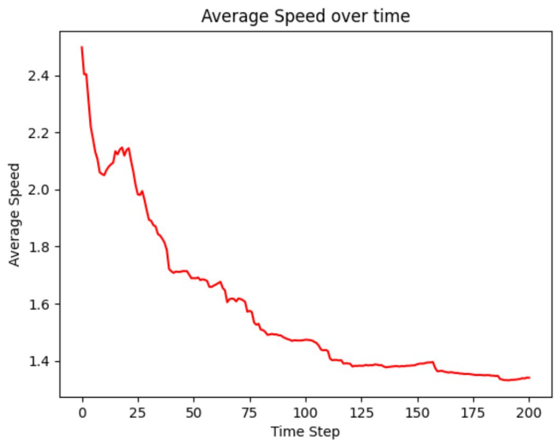
3 Results

The following constants were chosen for our simulations:

Constant	Value	Notes
Grid size	64	$2^6 \times 2^6$ grid
Food cap	0.05	5% of the grid
Init creatures	0.01	We start with 1% of the grid being creatures
Steps	10000	Number of timesteps
Base energy	8	Base energy
Energy from food	5	Energy gained from consuming food
Energy from creature	8	Energy gained from consuming another creature
Energy ratio to reproduce	0.9	When energy level reaches 90% of the creatures max energy, it reproduces
Energy ratio for reproduce	0.2	20% of energy is consumed for reproduction
Number of children	1	Each reproduction only produces a single offspring
Mutation probability	0.01	There is a 1% change for each gene to mutate during reproduction

Table 2: Creature characteristics and their descriptions





Code is availabe at https://github.com/suren2003ah7/EvolutionaryModel.

4 Discussion

We have simulated the model with several cases, however we may try on more complex cases.

1. Random genes. Try many random genes for creatures and see if we reach equilibrium of one gene.
2. Strong specific genes. Start with high values for specific genes and see if we reach equilibrium or not after mutaitons.
3. Record the evolution of each gene by averaging that genes during each timestep.

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