TJHSST Senior Research Project
Simulating Evolution
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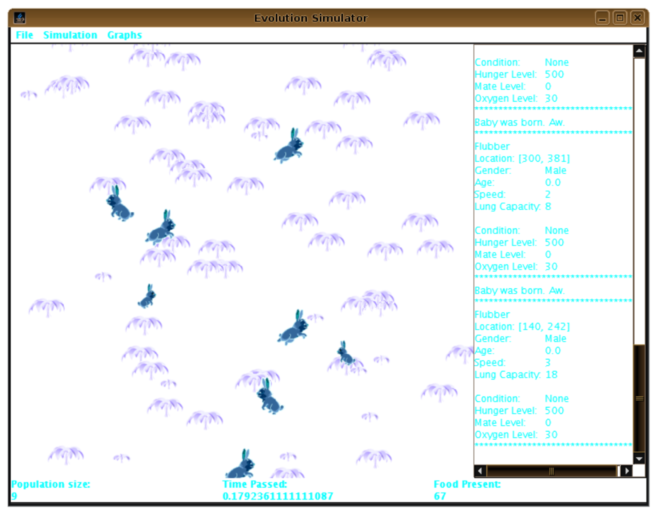
Abstract

The main purpose of this program is to accurately simulate the genetic evolution of a species.It will attempt to do so using the most common evolutionary device known as genetic drift, a means of microevolution. This project is actually one or Agent-Based Modeling and Simulating (ABMS) in which the organisms are the agents that react with one another and their environment.

Keywords: genetic algorithms(methods of representation, methods of selection, methods of change), evolutionary computation, genetic mutation, genetic drift, optimal state, microevolution, macroevolution, Darwanism, natural selection, genetic variation, recombination, gene flow, speciation



1 Introduction

1.1 Rationale

The computer will simulate an environment and the user can modify that envirnment. Modication of an organism environment can force it to adapt and in essence, better survive. Because of this, those that are not adaptable to the change will die off and those that are will live on and reproduce, thus creating a genetic drift in the species. This is the theory. According to this theory, one should be able to predict the changes in a species genetic make-up due to a change in its environment. If the environment becomes hotter, those creatures with higher temperature tolerance should be less affected than those without a high temperature tolerance and so one would expect to see the species evolve to have a greater tolerance to higher temperatures. My project tracks speed as the adaptable trait.

1.2 Purpose

Evolution often thought of as the changes that occur in an organism to better suit them to their envirnoment. However, this is not completely true. Evolution occurs in both positive and negative directions. It is completely random and the result could be in favor of the organism or it might not. It just so happens that the organisms resulting from an inefficient "evolution" do not survive and thus the species are left with the more fit species that will reproduce and populate. I am trying to simulate evolution and track the change in a species' traits to better understand how evolution really works and more importantly, to experiment with genetic aglorithms as represented in Computer Science.

2 Background

"Genetic changes do not anticipate a species' needs and those changes may be unrelated to the selection pressures on the species. Nevertheless, evolution is not a fundementally random process."[3]

Agent-Based Modeling

The actual evolution simulator is an ABMS with the Flubber class forming the 'agents.' An agent is "autonomous and self-directed." It can "function independently in its envirnoment and inits dealings with other agents." Mostly, an ABMS focuses on the interations between the agents. In this project, I will be observing both the interations between the agents and the interaction between the agents and their environment. [8]

Basic Concepts

A population of any given species is greatly affected by its environment. This is where an animal will get its food and raise its young. In order to do this, it has to be well adapted to the environment it lives, yet also able to change under stress (such as a change from the norm). This is when evolution will occur. The members of a species that are best able to handle stress are the ones that will live on to populate the species; therefore, their young will aquire the more desired traits and be able to live in the newly changed environment. The environment in which a population lives provides resources for the population such as food and shelter. If there is limited food, then the environment will only be able to support a given number of species, meaning that the population will have a max value. The function of the population over time should be logarithmic, approaching that max value. Howver, this is just a basic model of an environment, void of predators and many other factors that affect the size of the population. If there are predators, then the population size should oscillate in accord with the predators (though there is a slight lag in the predator's population graph). [7]

1. Mechanisms that Decrease Genetic Variation[1]
   (a) Natural Selection
   Natural selection was introduced by Charles Darwin. It is when the frequency of the more prolific members of a species increases because they are better adapted to the environment.
   (b) Genetic Drift
   This occurs when the allele frequency changes (can allow mutant alleles drift into fixation).
2. Mechanisms that Increase Genetic Variation[1]
   (a) Genetic Mutation
   This occurs when the gene sequence altered because the copy of "DNA" is corrupt.
   (b) Recombination
   This includes crossover of genes from the mother and the father to produce genes of the child(gene shuffling).

(c) Gene Flow

Gene flow occurs when genes drift into a population from a different population through mating. (This is not implemented in this project.)

3. Types of Evolution[1]

   (a) Macroevolution

   Macroevolution includes speciation, or the seperation of one species into two. It is an evolutionary change at or above the species.

   (b) Microevolution

   Microevolution is evolutionary change below the species level.

4. Types of Genetic Variation[4]

   (a) Variation Under Domestication

   (b) Variation Under Nature

3 Development Sections

3.1 Requirements, Overview, Limitations, Development Plan

The minimum requirement for this project would be an environment that includes the species under evaluation. There obviously must be a species to study and that species must have traits that can be altered, affecting its ability to survive. The environment must also provide a regenerating food source for the organism being studied else it will not live long enough to produce various generations leading to evolutionary results.

The project's main limitation is time. To single-handedly write an accurate evolution simulator is very tedious and time-consuming especially since many problems occur, some of which cannot be fixed and a new method must be discovered. Also, the speed oft he computer is a limitation since running a simulation with millions of agents is a task that only a supercomputer can handle (or not, depending on how much each individual agent 'thinks').

Software

1. Java

3.2 Research Theory and Design Criteria

Main classes

1. Blubber class

   - Description

     The sole purpose of the Blubber class is to provide food for the Flubber class. It stored the amount of energy it contains. As it gets older, it will grow bigger and thus the amount of energy it contains will increase. (If a Flubber eats an older Blubber it will gain more energy.)

2. Flubber class

   - Description

     The Flubber population is the species that is being studied. It contains changeable traits in its 'DNA' which determine the characteristics of its children (unless they be claimed by mutation).

   - States

     Each Flubber has four states: hungry, sexy, drowning, and curious. A Flubber bases its next action on its current condition. If it is hungry, it will search for food to eat or return to a nearby location from memory. If it is sexy, it will search for a mate of the opposite sexy that is also sexy. If it is drowning it will retrace its steps until it is no longer lacking in oxygen. Finally, if the Flubber is none of the afore mentioned conditions, it is curious. When a Flubber is curious, it will freely roam about its environment, noting the location of food that it 'sees.'

   - Memory

Flubbers have two basic memories. One is devoted to known food locations while the other is devoted to recent steps taken.

- Genes

  When two Flubbers mate, their genes are collected to determine the genetical make-up of the offspring, though randomly mutation will occur and the child will recieve a gene that is not of its mother or father.

3. Environment class

   - Description

     This class contains all the Flubber and Blubber objects in the environment and allows them to react with one another. It has two HashMaps; one for the Flubber population and one for the Blubber population. This class also provides the GUI for the simulation and is the portal for user input.

Algorithms

1. Process for Recombination

   The process for creating a new organisms with a new combination of genes mixed from its parents (and sometimes randomly mutated) takes the traits from both parents and gives the child a trait that is either equal to one of the parents, or is a mix of the two (something in between). The assignment of the trait is semi-random.

2. Randomization for Mutation

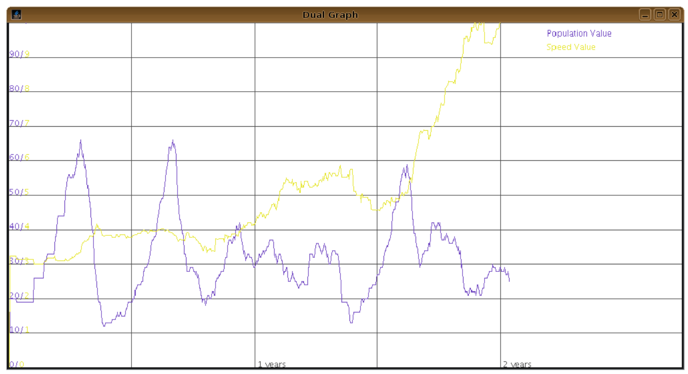
   The process by which genes are mutated is completely random. In fact, it is double random because the swapping of genes is random and the chance that it is mutated is also random.

3.3 Testing and Analysis

This model has proved to be much more successful than its predecessor. Because there are no predator, the system is less succeptible to balancing problems. I have run this simulation consistently for 10 hours and the population of Flubber agents does not die out. Also, the Flubber class has gone through much testing because it is the main part of the simulation. I have had to test and correct all the methods, the most tedious being the breed and move methods.

3.4 Visual Representation of Data and Results

I have created a Graph class and a DualGraph class which extends it. These classes provide a graphical display of the Flubber population changes and the change in the trait value (in this case, speed). A picture of such a graph is displayed below.



3.5 Development Procedures

Steps to Simulating Evolution

1. Create a changing environment with which a species may interact

2. Create a food source for the species

3. Create a species with designated traits to be tracked

4. Create an herbivousous species

5. Define how the species may evolve (genetic algorithms)

6. Track the changes in traits and make obsevations

4 Results, Discussion, Conclusion, Recommendations

With the new model in place, the program runs quite smoothly and the graphs provide a good graphical display of what is happening. It behaves almost as one would predict with an oscillating population value and a trait value that shows an upward trend (evolution for the better). From the DualGraph, you can see that the trait values usually show a rapid increase when the population is very high. Because the trait I am tracking is speed, this makes a lot of sense. As the population gets high, the availability of food decreases and the ability to get to food quicker becomes an important survival skill; therefore, the aganets with greater speed will live on to reproduce while those with lesser speed will die out, increasing the trait average for the population.

5 Literature Cited

References

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