Project Report
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Background: The theory of evolution was first proposed by the 19^{th} century naturalist Charles Darwin and has undergone much change since then to become a pillar of modern biology (Dawkins, 1976, 1996). The core idea of evolution is that genes, which enable an organism to compete better, will give that organism the opportunity to create more offspring on average. This leads to a survival of the fittest situation in which those genes that are best suited to survive in their environment will do so. For a wide variety of reasons, genes are sometimes copied from one generation to the next with errors or mutations. Most of the time these mutations will either have no significant effect or will reduce the ability of an organism to survive, but sometimes they will make it more fit. These rare improvements will often be picked up by natural selection and come to be present in a large portion of the population. Thus, species are able to slowly change to better survive in their environment and eventually may bear little resemblance to their predecessors (Johnston; Quinlan).

The problem with trying to learn more about evolution and perhaps one of the reasons that such a solid theory is still debated today is that it operates on a massive time scale that is beyond most human observation. Unlike many scientific theories, evolution cannot be reduced to a "test tube" situation in which all other variables are controlled and the process can be seen. Firstly, this is because of the fact that any scientist would be long dead by the time he could collect any meaningful results. The second problem is that life is hugely complex. To quote Douglas Adams: "*Supposing you're trying to find out how a cat works--you take that cat apart to see how it works, what you've got in your hands is a non-working cat.*" This second problem combined with the problem of creating an environment to stimulate evolution prevents repeatable tests from being performed even with bacteria that have extremely short generations of around five minutes. Building a model to observe controlled evolution would be desirable as it would allow us to perform tests of the process.

Good models allow us to simplify and control real world situations while losing the min-imum amount of accuracy. Population dynamics, the study of patterns in wild population numbers, is different from evolution in that it can be observed much more easily in reality. It is still desirable to test population dynamics, however, as a good model will allow much easier tests and results than we could get from observing nature. No model can be perfect but models are still in-credibly useful.

Purpose: The purpose of this project is to write a computer program that is able to model the broad concepts of evolution and population dynamics. The purposes of most scientific experiments can be simplified to the question "What happens if I do this?" The main purpose of this project is to create, with as much accuracy as possible, an environment in which one can ask many different "What happens if I do this?"s in relation to evolution and population dynamics..

Hypothesis: This project has been divided into many mini-tests in which the program is used to test various evolutionary principals and the program itself is tested. Thus, there is no grand Hypothesis but each test has its own.

Procedure: For each individual test, a different procedure was used. Here, however, an overview of the program as a whole will be given, as it is the core of the project and thus every procedure. The program is written in the Turing 4.04c programming language. The details of the actual code and the specifics of the functions and classes would be monotonous and long to both write and to read so here the program shall be described in terms of how it works on a broad level and what it does.

Everything that goes on in this program is based on a two dimensional grid. Each grid square represents an area of space that can be occupied by an organism. Squares can have a hot, moderate, or cold climate which can be detrimental or beneficial to an organism occupying it depending on the organism's genes. The basic time unit used here is the cycle. In each cycle, organisms can interact (move, reproduce and eat) with neighbouring squares.

Organisms in this program interact with their environment (including other organisms) based on their genes. There is (at the time of writing) a set of eleven genes which represent large numbers of real life genes and encompass types of genes rather than specifics. There are, for example, no genes for sharp horns or legs designed for running. Instead there is a gene that specifies an organism's ability to resist predators. This format was chosen because specifics would reduce accuracy. One cannot feasiblely include all possible specific genes and the potential for new ones to be created and changed slightly. Thus, it is much better to work with categories. Some genes have Boolean on or off values while others have values from one to ten. Note that this is not a denial of Mendelian genetics. Genes with scales would be combinations of many genes in reality.

Each time an organism reproduces; there is a small chance that there will be a mutation. This chance is many, many times larger than in real life but this is necessary because we want to actually see something happen in our lifetimes.

The basic currency of life here is energy. Energy represents actual energy as well as essential nutrients like nitrates and phosphates. Energy enters the system through photosynthesis and is (with realistic inefficiency) passed up the food chain to herbivores and so on. Organisms without any energy will die. When testing population dynamics, one can set a limit to the amount of photosynthesis that goes on in each cycle. This represents the limits of an environment that would occur in real life. Organisms going too close to this limit are damaging their environment and will reduce the limit while organisms that are far below a reduced limit are applying hardly any stress and can cause the environment to recover.

Results: Note that the full results for this project are around sixteen pages long and due to length limits, could not be included here. The results below are in an extremely abbreviated form. The experimenter decided to give more space for the above sections as results would be meaningless with no explanation.

Test 1: Asexual reproduction was put into controlled competition with sexual reproduction. Result: though asexual reproducing organisms succeeded at first with their efficient reproduction, they were eventually defeated by more adaptable sexually reproducing organisms. This can be seen in the real world.

Test2a: Here a plant population was left to develop through selection for one hundred cycles. After this, herbivores were introduced and the effects were observed. Interestingly enough, the plants eventually adapted to be unable to be eaten. Their high numbers produced many more useful mutations than the herbivores could compete with. After some consultation with a biology teacher, it was discovered that, in reality, such an immunity adaptation would hardly ever occur and the majority of times prey adaptations would be deterrent and not preventative. Thus this test is a special case scenario.

Test 2b: Population crashing and environmental damage was turned on for this and the above was run. The situation repeated itself except that once the plants had "defeated" their predators; they grew quickly, damaged their environment and crashed. This is what would happen in reality (Andrews, 1986).

Test 2c: In this test, the first program was run except that the introduced herbivores were far more proficient at getting around plant defences than before. The herbivores wiped out the entire plant population, as it was not able to adapt quickly enough.

Test 3: A single population of plants was placed in a central moderate climate area which bordered on both a hot and a cold area. The population diverged into three groups of climate specialists. A follow-up was run in which the climate zones were switched after the development of specialists.

This resulted in devastation but there was gradual recovery.

Test 4: An attempt to create a balanced ecosystem was made. Many problems were encountered, however, because of the limitations of the grid. This test resulted in a failure to create a balanced ecosystem but many insights into how the program could be improved in further work.

Test 5: Here a group of highly inefficient organisms were put into close quarters to compete. The selection for efficiency was huge and the population became efficient quickly. This shows how a markedly beneficial mutation with an inherent advantage will almost always get picked up and spread rapidly.

(Short) Conclusions: There are numerous ways in which this program could be improved if the experimenter had the time. These include a more realistic genetic system similar to the one described at the Collage of Science and Technology website sited below, the possibility of genetically programmed altruism and tests of its effects, and a more realistic simulation of space and terrain. Despite this, the program succeeds in simulating the principals behind natural selection and population well. Mutations that are beneficial in their environment will be picked up on and will spread. Populations will gradually adapt to their environment and populations that are out of balance will crash. Thus, the program has achieved its goal of simulating broad biological laws very well.

References

1.Andrews, William A(1986). *Investigating Terrestrial Ecosystems*. Scarborough: Prentice-Hall Canada Inc.

2.Dawkins, Richard (1996). *The Blind Watchmaker*. New York:Oxford University Press

3.Dawkins, Richard (1976 -with 1989 last chapter). *The Selfish Gene*. New York: Oxford U. Press.

4. Johnston, Ian. Malaspina University-College, Nanaimo, BC. And Still We Evolve. Retrieved Oct 21, 2002 from: http://www.mala.bc.ca/~johnstoi/darwin/sect5.htm

5. Quinlan, R. Ball State Univerity. Basics of evolutionary theory. Retrieved Oct 20 2002 from: http://www.bsu.edu/web/rquinlan/anth105/basics_of_evolutionary_theory.htm

6. Unknown Author. Island university: Collage of Science and Technology. Genetics. Retrieved Oct 20, 2002 from: http://www.sci.tamucc.edu/~chopin/biology1/fall99/Genetics,_Bio_I_99.html