WATCHING EVOLUTION

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BACKGROUND, PURPOSE AND HYPOTHESIS

Evolution is sometimes described as a blind watchmaker.[1] It can seemingly engineer complicated systems with no apparent direction or goal. In reality, evolution is the result of numerous random genetic mutations accumulated over time by a non-random process, natural selection.

This project was created to investigate evolution as a literal "blind watchmaker", drawing inspiration from the YouTube video *Evolution IS a Blind Watchmaker*[2] and the BBC documentary *The Blind Watchmaker*.[3] The project was carried out by writing an original C++ computer program which modeled mechanical pendulum-clocks as collections of heritable data within a population and applied algorithms based upon natural selection.

The purpose of this project was to model the evolutionary process on computer simulations of mechanical pendulum clocks, and to determine the effect of several different environmental factors on the evolution of these 'living' clocks.

The hypothesis was that, if a process of evolution by natural selection can be simulated and quantified, then there should exist correlations between the environmental parameters in the simulation and the evolution of the populations.

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[1] Dawkins, Richard. The Blind Watchmaker: Why the Evidence of Evolution Reveals a Universe without Design. New York: Norton, 1996.
[2] "YouTube - Evolution IS a Blind Watchmaker." YouTube. 25 Oct. 2008 <http://www.youtube.com/watch?v=mcAq9bmCeR0>.
[3] The Blind Watchmaker. Perf. Richard Dawkins. DVD. BBC, 1987.

Procedure

The procedure followed by the program varied depending on the parameters chosen for a particular simulation, as the parameters were the independent variables for the experiments. This is an example of a procedure used for a simulation with the control set of parameters.

1. Initialize a population of one thousand clocks filled with random genetic data.
2. Choose three randomly selected clocks from the population.
3. Of the three chosen clocks, rank them best to worst based on a fitness score that is a function based on accuracy, connectivity and efficiency of parts, and clock-like traits such as the presence of hands.
4. Of the three chosen clocks, delete the clock with the lowest fitness score to represent natural selection.
5. Create offspring using the two remaining clocks as parents and sequentially filling the offspring clock with genetic data, copying genes with a 49.5% chance from either parent with a 1% chance of mutating a random gene.
6. Replace the deleted clock with the newly created offspring clock.
7. Return all three clocks to the population.
8. Repeat steps 2-7 one thousand times. This represents one generation.
9. Repeat step 8 for two thousand generations.

Results

General Results:

The fitness score of an individual clock was used to determine its fitness; thus, the average fitness score of populations was used to measure the population's fitness for the environment throughout the simulation. The average fitness score of a population was found to increase in a 'staircase' pattern, alternating between long periods of stability and short periods of relatively rapid change. This pattern was observed in each of the hundreds of simulations without exception. This pattern of the fitness score incrementing in 'steps' is outlined in Figure 1.

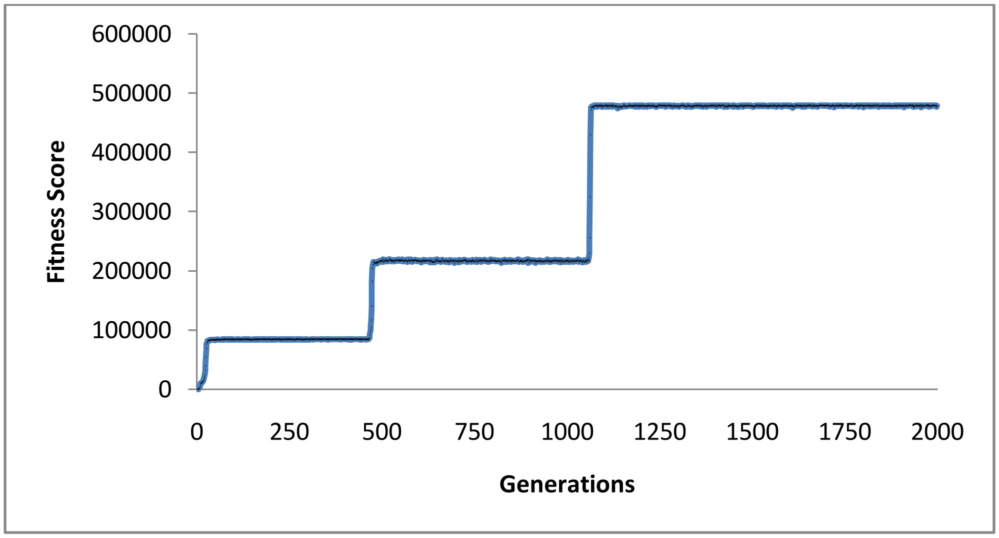

Figure 1. An example of the average fitness score of a population across 2000 generations.

It was determined that the cause of the short periods of rapid change was the exponential propagation of beneficial traits throughout the population.

Parametric Results:

The selective pressure magnitude (SPM) controlled the balance between the importance of quantitative and qualitative traits in clocks (e.g. gear intervals or presence of hands) by acting as a score multiplier for the qualitative traits. It was found, by measuring the average pendulum period of the population, that the optimal SPM value was roughly 10x, as increasing the SPM value resulted in heavily unbalanced selection for qualitative traits.

The population size was found to be beneficial for the population, as an increase in the population size was found to reduce the percentage of non-functional clocks in the population and reduce the number of simulations undergoing a phenomenon dubbed "Stuck Pendulum Syndrome" (SPS). SPS was defined as a simulation that had its entire functioning population dominated by simple pendulums, rather than 'true' clocks, at the end of the simulation. A simulation in SPS would effectively stop evolving.

The genome size of the clocks was found to be proportional to the percentage of non-functional clocks in the population. However, it was inversely proportional to the number of simulations in SPS. Thus, increasing the genome size would decrease the likelihood of having simulations in SPS while increasing the likelihood of non-functional clocks, and vice versa.

The percent chance of mutation upon copying genetic data was found to be proportional to the percentage of non-functional clocks in the population. However, while a mutation rate of zero percent resulted in a population with 100% functional clocks, the populations could not progress past simple pendulum configurations due to the lack of new genetic data. Thus, a mutation rate of zero percent caused a large number of simulations to undergo SPS. Increasing the mutation rate above zero did not have any observable effect on the number of simulations undergoing SPS.

<u>Confirming the Effects of the Parameters:</u>

Another experiment was done comparing the default parameters to 'optimized' parameters determined by analyzing the results of the parametric experiments. The 'optimized' parameters increased the population size to 10000 clocks, and reduced the mutation rate to 0.5%. The results found that the optimized parameters reduced the number of simulations in SPS from 3 to 0, and the average percentage of non-functional clocks from 21% to 6%. A Student's t-test was used to confirm that the average percent of non-functional clocks was significantly decreased.

CONCLUSIONS

As shown in Figure 1, it was found that populations of clocks did not evolve linearly, but rather progressed in a series of 'steps'. This supports the model of punctuated equilibrium.[4] In other words, this experiment found that as populations evolve over time, they alternate between long periods of stability and short periods of rapid change caused by beneficial genetic mutations.

It was also found that non-biological systems could be built and improved upon through the application of evolutionary algorithms. The implications are that other similar systems capable of being modeled as matrices of heritable data and subjected to a struggle for survival can be improved by the evolutionary algorithms used in this project. An example of such an application would be the development of camouflage, through the modeling of surfaces as matrices of pixels.

The hypothesis was supported by the results from this project, as correlations between the population size, genome size, mutation rate and the successful evolution of the clocks were found through measuring the amount of simulations in SPS and the percentage of non-functional clocks in simulations.

ACKNOWLEDGEMENTS

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[4] Allott, Andrew. Biology for the IB Diploma. New York: Oxford UP, 2007.

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