Dynamic Complex Dinosaur Ecosystem Simulation
TJHSST Senior Research Project Proposal
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Abstract

Ecosystems are based on the multiple interactions between the individual parts (the species and environment) coming together as a whole. Thus, in order to effectively evaluate changes on an ecosystem and to evaluate the end product of individual objects in an ecosystem, the ecosystem must be examined as a whole. This requires many species and many interactions and many variables - too many to be done by simple equations or small algorithms. The ecosystem must be run/simulated in order to be modeled by a computer. Major inside population changes in an ecosystem include evolution, adaptation, population fluctuation - chance events that effect the existing population, based on the existing ecosystem. On the other hand, major outside changes to an ecosystem include natural disasters, invasive species, new species - chance events that do not come from the existing population that do effect the ecosystem. How will these events effect a dinosaur ecosystem set in the late Cretaceous Period? What can the applications be of such a simulation?

Keywords: ecosystem, modeling, simulation, adaptation, evolution, population, species, disasters, dinosaur, factors

1 Introduction

Problem Statement and Purpose

The purpose of my research project is to create a simulation of a many-species, non-static, many-variable ecosystem based on the dinosaurs. According to user preferences, many desired ecosystem simulations will be able to be run. This means that the simulation will include hypothetical situations, which will be applicable to real-life, and a real-world model. There are many applications such as recreating events involved with dinosaur-based research such as palentology. Other applications include dinosaur research and drawing conclusions based upon these simulations. This simulation will use a chance-based predator/prey ecosystem (for predation rates), reproduction algorithms for evolution, adaptation algorithms, trait accumulation, new species, and natural disasters. This will first be done in NetLogo to facilitate display/debugging/testing, then will possibly be moved into Python for a more applicable and general programming language.

2 Background

Earlier background research corresponded to sources about predator-prey models and ecosystems involving evolution and adaptation. Further background research with a narrowed focus corresponded to sources about dinosaur predation and characteristics.

Operations Research and Modeling (Predator-Prey Model)

- The article of the Predator-Prey model was written by Dr. Hoppensteadt and detailed various modeling equations to estimate or predict the behavior of populations of various species today, accounting for various factors. The Lotka-Volterra model focused primarily on a linear population growth rate and is very applicable to simple ecosystems and a predator-prey relationship. The Kermack-McKendrick model accounted for the large populations of an active prey against consumers, termed 'herd immunity'. The Jacob-Monod equation took into account a steady rate of uptake for a population, usually used to measure species such as bacteria or parasite that would not be able to survive with constancy. Ricker's reproduction equation measured reproduction in cannibalistic or 'self-predating' species, and accounted specifically for the time factor.

- This source highlights the many factors that I need to consider with group populations regarding dinosaurs, however the actual equations are based on either different species types and/or are not applicable to the time period millions of years ago.

Primary research and Modeling (Fossil Record in Predation):

- The article of the Fossil Record in Predation detailed the various specific characteristic features of different dinosaur species and how they were used. Predator dinosaurs are especially recognized by the features of jaws, teeth, and other bone structure. With these characteristics along with other evidence from prey species, bites, gut contents, etc, how much about how exactly these predators hunted could be determined. These characteristics determined how dinosaurs behaved and lived their lives: from the claws for ripping, talons for restraining prey, molars for grinding leaves, or body parts for reaching various areas.

- This source highlights the many characteristics of dinosaurs that must be considered within inter-species conflicts.

Qualitative research (Biomechanics of Running Indicates Endothermy in Bipedal Dinosaurs

- 'Endothermic animals' refers to the animals that are warm-blooded and can maintain their internal temperature at a roughly constant level - homeostasis, regardless of the environment (cooling down and producing body heat). Were dinosaurs endothermic? Exothermic? Something a bit of both? They share both common trains with endothermic birds and exothermic reptiles. Based on metabolic rates and daily energy consumption, scientists have done research that suggests the bulky dinosaurs would have likely not survived long with an exothermic structure - heat energy must have been preserved.

Quantitative research (A jump-growth model for predator-prey dynamics: derivation and application to marine ecosystems)

- This source explores the dynamics behind an evaluated marine ecosystem. Specifically, it was determined that the biomass of the predators undergo a transformation in order to catch more prey. Usually, these predators were much bigger than the prey presented. Given the research, a master equation was given related to the Lotka-Volterra equation that allowed a researcher to calculate the biomass in a certain marine ecosystem.

- This source stated that real-world applications were heavily limited.

Research and development (NetLogo)

- NetLogo was the program that I used to run the simulation of the dinosaur ecosystem. Within NetLogo itself, simple models regarding predator-prey (such as wolf-sheep predation) have been created. In addition, the program runs on its own unique language and methods, so research was needed to determine how to operate it. NetLogo was developed at Northwestern.

3 Goal

The goal of my project is to provide a working simulation that will use many variables in order to simulate a dynamic complex dinosaur ecosystem in the late Cretaceous Period. In doing so, I am attempting to accurately recreate situations may have happened on our planet millions of years ago. In addition, outcomes of hypothetical situations based on varying species populations may be evaluated. The dinosaur ecosystem will exhibit behavior and trends of modern ecosystems and also apply related principles.

4 Design Criteria

In order for my program to achieve its working goals, it must implement at least a base set of variables that can be manipulated to the user's needs. The most basic of all my variables will be species - there will be producers, consumers, omnivores, etc. Ideally, it will be able to control the number of these species to a certain degree (5-10 species is the desired amount) and also control the populations. Next, expansion will occur by introducing a trait factor for each of the species. According to the theory of natural selection, this will be like a real-world ecosystem and continually improve the existing populations because those with unfavorable traits would become nonexistent. The trait passing algorithm will be based upon the Punnett square (a simple matrix) and a survivability factor. In addition, various natural disasters will be implemented, along with population characteristics. Natural disasters are the catastrophic events that effect the ecosystem, and the characterstics of the different species will mean that different natural disasters affect each species differently.

5 Procedure

Using NetLogo, which will likely be turned into Python given time, I will be programming from the bottom, and expanding on the simple variables in order to create more complex variables. Eventually, there will be a complex dynamic ecosystem with a large amount of variables for optimum user control and definition of the ecosystem. At the end, the program (NetLogo) will be able to store data in a spreadsheet using the BehaviorSpace method. Currently, operating the simulation is as simple as sliding bars to provide integer values for inputs (dynamic variables), then setting up and running using the appropriate buttons. Next, I will evaluate the resulting data in comparison to conventional ecosystem behavior.

6 Scope

In the first quarter, I programmed the bare basics such as the predator-prey ecosystem, added herbivore-producer relationship, added basic predation algorithms with prey loss, and recorded data by using a modeling algorithm. In the second quarter, I shifted to the Dinosaur focus as the result of wanting to narrow down the topic. I chose to then further narrow the topic by focusing on the late Cretaceous, adjusting the movement algorithm, a predation range algorithm based on the move speed and endurance of different species, adding additional 2 species, fixing reproduction algorithm (which was previously asexual), and working prey selection algorithm along with a predator-prey conflict where the prey can affect the predator in its self-defense. By the end of the 3rd quarter I will probably have implemented many more dinosaur species. There could be more than one type of producer, water factors, geological factors, natural disasters, and possibly egg-periods where the offspring arrival into the ecosystem simulation is delayed (hatching).

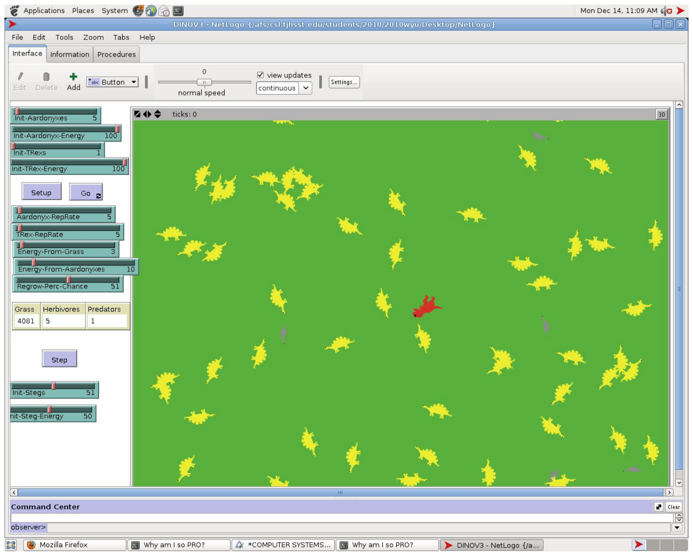

Figure 1: Example of a final result.

7 Expected Results

The expected behavior / results of my simulation will probably be indicative of the normal standards of population behavior or conventional ecosystems today, when certain stresses or variables are predominant (for example, the theory of natural selection). The simulation should run reasonably given its inputs and the characteristics known about the various species of dinosaurs.

What contributions can these results give to future researchers (next year's seniors who would like to do a similar project, for example)? This will make it easier for future researchers to expand upon my project and add variables, change variables, and hopefully make it more realisitic. In addition, future researches can focus on a different time period, different species, or a different simulation events. For future researchers considering a predator-prey evaluation, the complex relationships based on the various species in my research project can be a goal to surpass.

What time frame do you think you will need to accomplish the identified tasks and subtasks? I expect to be finished at the end of the 3rd quarter, the expected time frame.

References

[1] A Jump-Growth Model for Predator-Prey Dynamics. http://arXiv.org.

[2] Biomechanics of Running Indicates Endothermy in Bipedal Dinosaurs. http://www.plosone.org/.

[3] Cellular Automata Model of Macroevolution. http://arXiv.org.

[4] Dr. Frank Hoppensteadt. Predator Prey Model. http://www.scholarpedia.org/.

[5] NetLogo Website. http://ccl.northwestern.edu/netlogo/.

[6] The Fossil Record of Predation in Dinosaurs. http://portal.acm.org.