Dynamic Complex Cretaceous Era Ecosystem Simulation
TJHSST Senior Research Project Proposal Computer Systems Lab 2009-2010

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Abstract

Ecosystems are governed by the multiple interactions between the individual parts (with elements from both the species and environment) coming together as a whole. Therefore, in order to effectively evaluate changes on an ecosystem and discover the end product result of an ecosystem, the ecosystem must be simulated and then examined as a whole, preferably at many points in time. This requires many species and many interactions and many variable, too many to be done by simple equations or small algorithms or vague estimations. Major and advanced factors that have not found their way inside of many agent-based modeling simulations regarding ecosystem-based population changes include chance events such as evolution and adaptation. On the other hand, other major outside changes to an ecosystem that are rarely accounted for include natural disasters, invasive species, self-cannibalization. While existing and current world species populations and conditions may be measured by modern equipment and then compiled into applicable data, precise data on species of the past is rarely consistent or applicable. Particularly lacking is information on ecosystems during the period of Pangaea, which have been estimated primarily by geological means and paleontology. It is my focus that I develop an answer to the question of, "How did a dinosaur ecosystem set in the late Cretaceous Period function?"

Keywords: ecosystem, modeling, simulation, adaptation, evolution, population, species, disasters, dinosaur, factors, cretaceous, Pangea, agent, data, period, chance

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, focusing on the late Cretaceous Period. According to user preferences, many desired ecosystem simulations will be able to be run. This means that the simulation will expand to cover many hypothetical situations, which will be applicable to real-life, and a real-world model. There are many applications such as recreating events in the distant past as discovered with dinosaur-based research subject studies like paleontology. Other applications include dinosaur research and drawing various individual and independent conclusions and uncovering possibilities based upon these accurate simulations. The simulation will use a chance-based predator and prey ecosystem with a gradually expanding non-symmetric food-chain, reproduction algorithms for evolution, adaptation algorithms, trait accumulation, new species, and natural disasters. One of the most important factors of all, time has already been implemented and is in use well within the program. Each individual specie will age, have conditions, and have limits to behavior. Specie variability is also a close probability in regards to traits such as survival rate. The ultimate goal is to maximize the representation of the simulation by accounting for as many factors as possible. 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. Data will be complied using a spreadsheet and then sorted appropriately.

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.

Qualitative Research (What Killed the Dinosaurs? The Great Mystery)

- Simply put, the goal of this research was to determine or make discoveries regarding the facts surrounding the extinction of dinosaurs. This was done by examining fossils, gathering data, making models, and creating hypothesis.

- Beginning with the 1980 UC Berkely proposal for the K-T extinction, this hypothesis jump started much of the research from many fields including astrophysics, astronomy, geology, paleontology, ecology, and geochemistry, and so on. Almost all the dinosaurs decreased in productivity along with the plants, all except the fern which dramatically increased known as the fern spike. Fossil record is being used to get hints about what may or may not have happened. This fossil research is being followed by figuring out the nature of death, the time of death, reconstruction of the fossil, and determining what and how dinosaurs died at the K-T mass extinction.

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 characteristics of the different species will mean that different natural disasters affect each species differently. Time is one of the major new implements to my project. Over time, dinosaurs can lay eggs given at least one mating partner and eggs take time to hatch. These eggs may be preyed on and if they survive a certain amount of time, they hatch and become little dinosaurs. Over time, dinosaurs begin to get bigger and bigger according to the size variable, eventually culminating in an age-based death if they manage to survive long. Additional species of different types can be added with little difficulty and are finding their own way into the ecosystem. The simulation counts the various aspects of its agents, with a heavy consideration for the agent count.

5 Procedure

Using NetLogo, 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 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), having the option to toggle on or off certain ecosystem-based functions, and then setting up and running using the appropriate buttons. The program automatically records all relevant information, and it can be run in time intervals of one step or continuously applied. This leads to evaluating the resulting data in comparison to conventional ecosystem behavior. Analysis is not a goal of the simulation, but accuracy of the provided data is foremost a priority.

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. In the 3rd quarter, I have implemented more than one producer, water spots, geological dead zones, natural disasters, and eggs. These eggs hatch after a delayed amount of time and have thier own type indicated by thier color (and size). These eggs can serve as food, but eventually turn into a miniature version of the original parent. There are a total of 6 natural disasters that effect the different elements of the ecosytem seperately in different ways. In the 4th quarter, I streamlined my algorithms, and added a few more species. In addition I did further research to add more species, and fixed some previously inefficient algorithms. I also did the majority of my research experiment during this section, choosing to run BehaviorSpace and many iterations of self-testing on various conditions.

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. See appended picture for example.

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 realistic. 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 by the time of the presentations near the end of the year. My program is currently working well and recording information, but not available for analysis or processing.

References

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

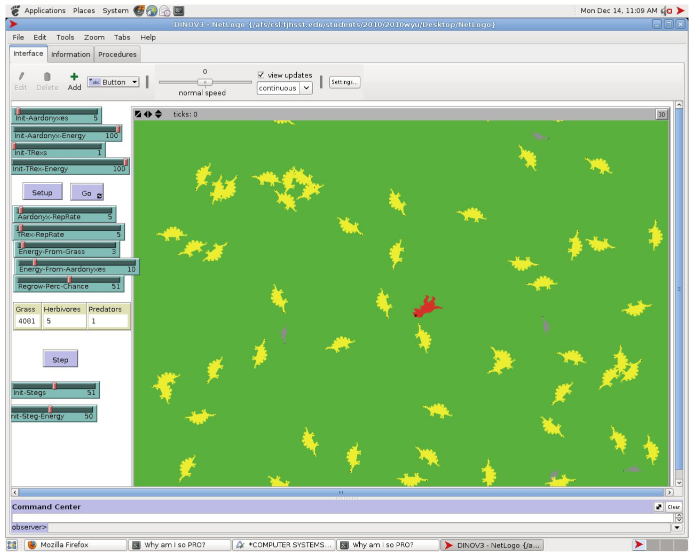

Figure 1: Example of a final result.

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

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