Statistical Analysis of Fluctuating Variables on the Stability of Predator Prey Relationships

Lenny Li
Computer Systems Lab 2009-2010

Abstract

Simple predation prey simulations greatly simplify the problem by assuming multiple variables to be a constant value, and thus are not very good predictors of a natural environment. In reality, a system will have multiple possible variables such as the size of the habitat, initial population sizes of both predator and prey, reproduction rates, the probability of a predator succeeding in killing a prey, the energy gained from either consuming a prey or consuming vegetation, and much more. This two part project will first compare a simulation that considers organism behavior and intelligence with one that is simple and random. I will then statistically analyze the effects, specifically the difference in stability of the simulation, of incrementing such changes listed above in a two species system.

Introduction

This project involves writing a program that models a single predator, single prey system, where both the prey and the predator depend on a food source to survive. Both prey and predator asexually reproduce offspring with random attributes. In order for a stable predator prey system to exist, a small group of prey must escape the increasing predator population. That prey population must also reproduce slightly faster than the rate at which the predators die. This allows the predator population a chance to bounce back into survival, and the cycle continues—hypothetically. With a simple predator prey system, the prey will all die off from the predators. Since all the prey are equal, none will be able to escape predation. The predators will then quickly die off from starvation. In order for a stable ecosystem to exist between predator and prey, some prey must be intelligent enough to escape predation and reproduce to continue feeding the predators. The first portion of the experiment involves demonstrating the effects of incorporating will analyze the magnitude of the effect of incorporating behavior and intelligence into a simple predator prey simulation. Having experimental evidence to support these theories would advance the validity of predator prey mathematical models.

The second part of the project involves conducting statistical analysis of the changes in stability when slowly incrementing certain variables in a predator prey system such as initial population numbers, the size of the environment, and the reproduction rates of both species. Using regression and hypothesis testing, we can determine if two variables are correlated in any way. We can then use this information to extrapolate the stability of a human controlled habitat such as a zoo or wilderness preservation after inputing these initial values. Of course, these values would only be a rough estimate of the true stability, but this project would be one step closer toward creating an artificial environment.

Development

We start with an NxN map with P predators and Q prey. The predator feeds on the prey and the prey feeds on the food growing in the field. During each step, the predator searches for food, attempts at hunting a target, checks if it wants to reproduce, and finally moves a distance of one unit in a random direction. Each predator is able to see the circle of radius 3 units around itself and searches for food in that area. The prey searches for food, checks if it wants to reproduce, and then moves a distance of one unit in a random direction. Currently, the characteristics of newborns are randomly chosen, with the exception of location, but that may change. In the simple predator prey model, all probabilities are determined randomly, with no input from intelligence or prey abilities. In the first version of the behavior model, basic behavioral effects were considered. For example, all organisms were assigned a "skill" level. The higher that organism's "skill" variable was, the higher chance it had of a favorable outcome during an enemy encounter. Also, organisms were less likely to reproduce if their energy level was low than they were to reproduce with higher energy levels. This incorporates organism intelligence, as it would not be favorable to divide an already low energy level with an offspring. A possible future development would be making more intelligent moves which means stalking a prey or escaping a predator.

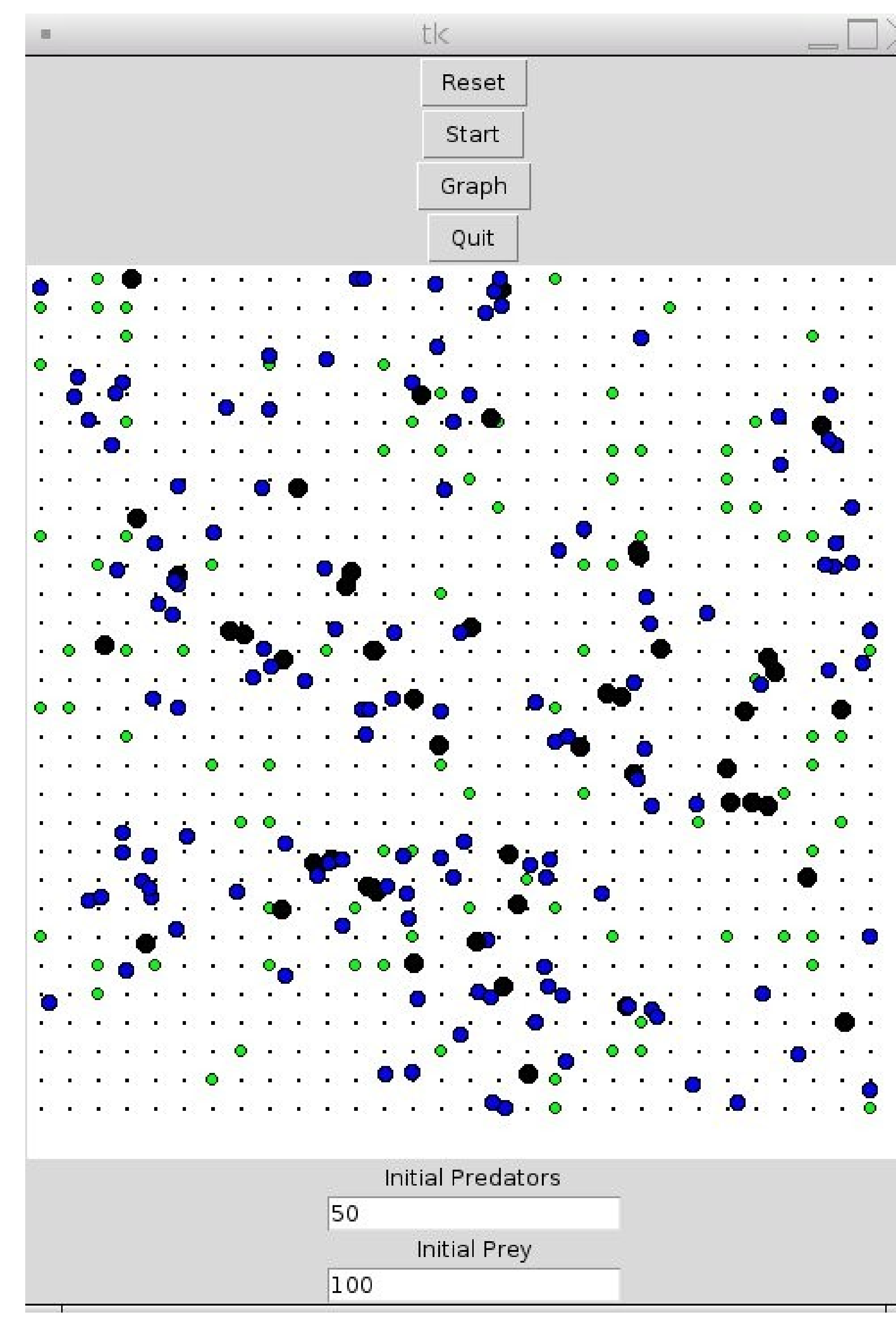


Figure 1. Simple Model

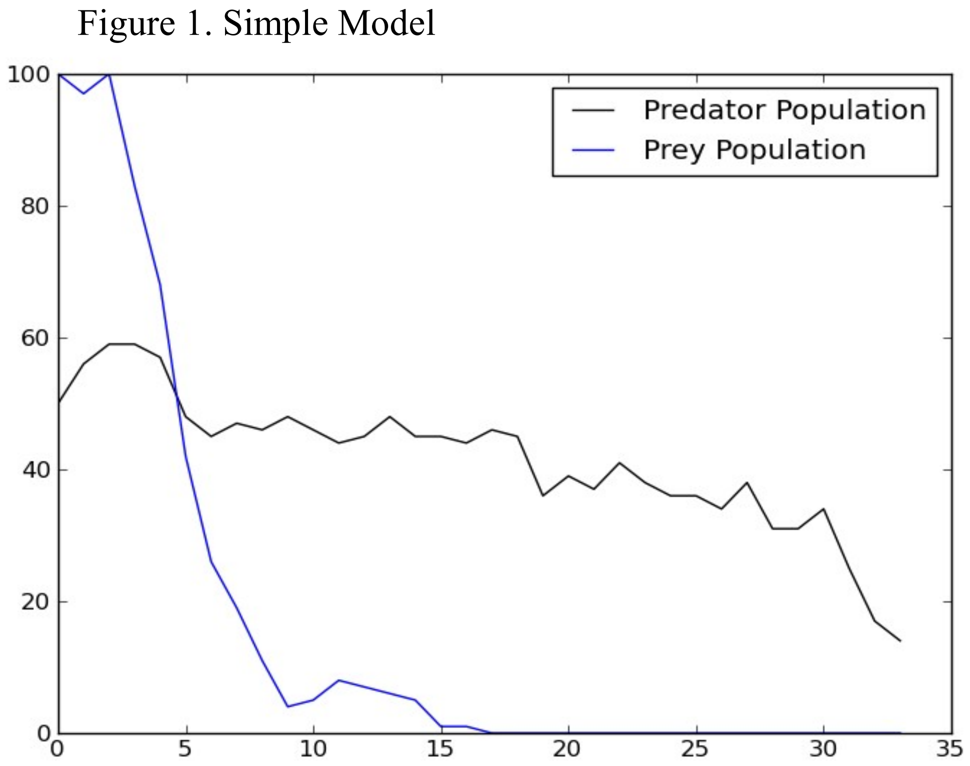
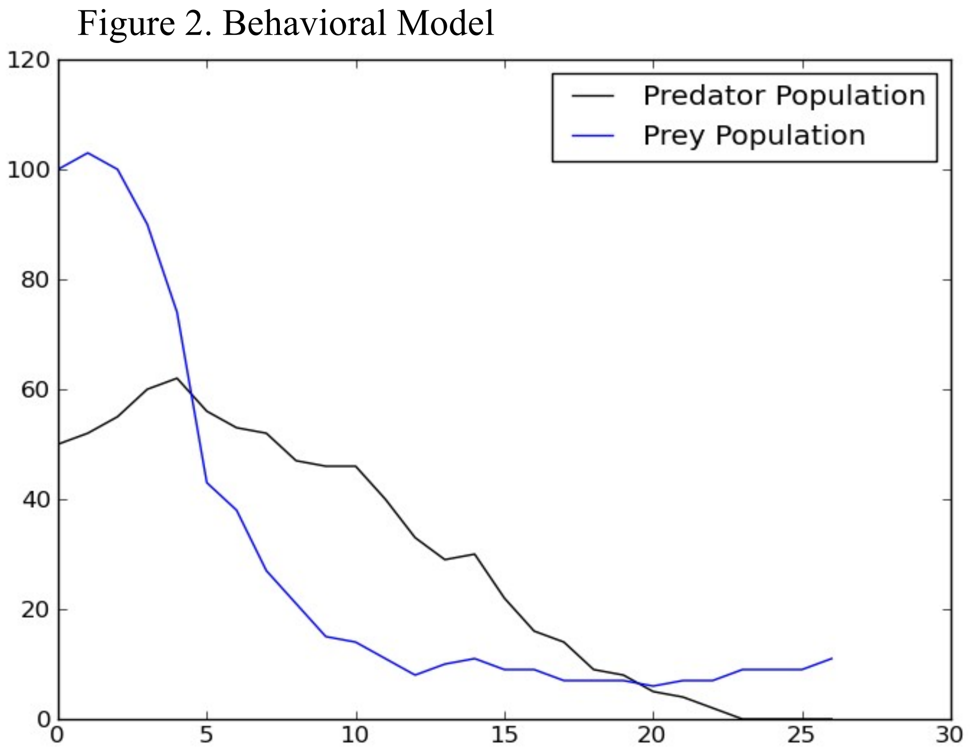


Figure 2. Behavioral Model



Discussion

Both programs were ran with the same initial N, P, and Q values. The graphs of population vs. time for both the simple model and the behavior model are shown in the appendix as Figure 1 and Figure 2 respectively. Multiple trials were ran, but they were mostly similar in outcomes. In the simple model, the predators immediately killed off all the prey and then died of starvation. In the behavior model, there were a few select stronger prey that survived from the initial predators. However, they could not reproduce fast enough to support the dying predator population, leading to a one organism system.

Analysis

After conducting a multiple regression analysis, I found an R-squared value of .22, which means that approximately 22% of the variation in the stability of the system can be explained by the correlation between the stability and the independent parameters. This may seem low, as we are generally hoping for a value close to 1, but imagine a basketball player improving his free-throw percentage by 22%. The p-values for each variable, except the prey reproduction rate, were all below our alpha value of 5%. This means that there is a statistically significant relationship between each independent variable and the stability of the system. The p-value is a measure of the probability that the correlation obtained is from pure chance if you assume the variables are not correlated. Since the p-values are so low (close to 0) we can conclude that there is some correlation between each of the variables and the stability of this system. The p-value of the prey reproduction rate, however, was 15%, so we cannot conclude any statistical significance between prey reproduction rate and the stability of the system.

Results

	Coefficients	Standard Error	t Stat	P-value
Intercept	186.4541457	2.186833616	85.26215453	0
Number of Predators	-0.556146663	0.011687164	-47.58610764	0
Number of Prey	-0.117070707	0.005442214	-21.5115973	6.0169E-102
Predator Reproduction Rate	-522.5348725	15.39290453	-33.94647655	2.4174E-248
Prey Reproduction Rate	15.32512626	10.53880129	1.45416218	0.145910785
Kill Percentage	-76.17841682	1.007702145	-75.59616419	0
Energy from Prey Gain	1.744611291	0.105388013	16.55417199	2.62974E-61

Regression Statistics	
Multiple R	0.478401111
R Square	0.228867623
Adjusted R Square	0.2287285
Standard Error	31.38794032
Observations	33264