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CS 4830

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Project 3 Simulation Report

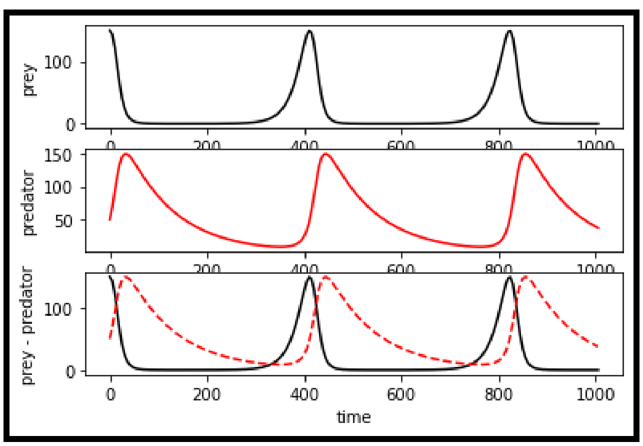
Section 1: Without Pesticide

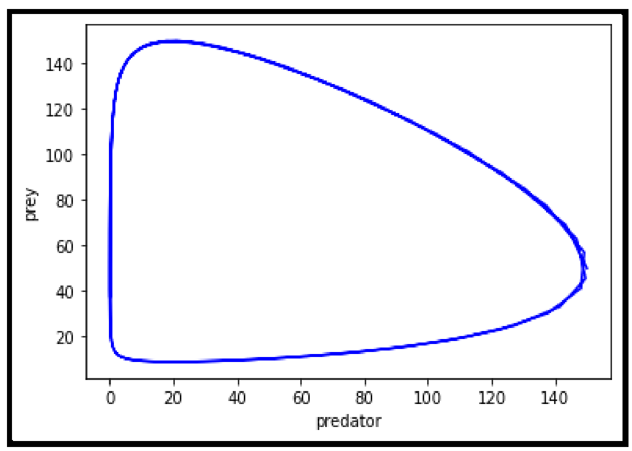
This assignment simulates the real-world biological system of predator and prey, with equations, commonly known as Lotka-Volterra equations, that represent the change in population of each species. The Lotka-Volterra equations closely mimic a real-world system as both populations directly affect each other, creating a pattern of growth and death in both populations. For this simulation, the predator is insects and the prey is grass. Because the insects prey on the grass, as the amount of grass increases, the insect population begins to increase as well. However, when the amount of grass begins to decrease as a result of the insects eating it, the insects will have less food and decrease in population as well. The resulting graph of population over time contains two sinusoidal functions, with one (the predators) slightly delayed behind the other (the prey). It also produces a graph of oscillating biomass of both populations.

There are two Lotka-Volterra equations in our system: One for the insects, and one for the grass. Each equation contains different constants for the birth and death rates of its respective species. The death rate of the grass is multiplied by the population of insects as well, because their death is dependent on the increase of insects. Similarly, the birth rate of insects is multiplied by the population of grass because their birth rate is dependent on the amount of grass. The resulting equations are as follows, with **x** = population of grass, **y** = population of insects, **α** = grass birth rate, **β** = grass death rate, **δ** = insect birth rate, and **γ** = insect death rate:

$$\frac{dx}{dt} = \alpha x - \beta xy, \quad \frac{dy}{dt} = \delta xy - \gamma y,$$

When simulating these two equations, it is useful to generate a visual, graph-representation of the data. The sinusoidal graph portrays the biomass of both species' populations and the blue graph shows the stability of the system and its ability to oscillate consistently. Changing the variables, dt and display interval, does not change the data itself, but affects how often the data appears on the graphs. The variable dt corresponds to the simulation's step size, which affects how often the state equations are updated. The display interval determines how many of those steps occur before the state is saved. Decreasing dt and/or display interval will increase the number of data points being calculated and the amount being shown on the oscillating graph, making it more precise. Increasing dt and/or display interval will make the graphs imprecise, especially the system stability graph, which will have more of a jagged appearance due to less data points being saved. All of the sinusoidal and stability graphs in this report, including the following two graphs, are created with a dt = 0.005 and a display interval of 1000:

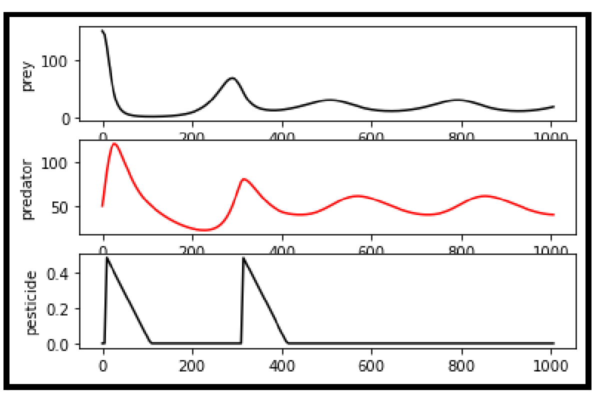


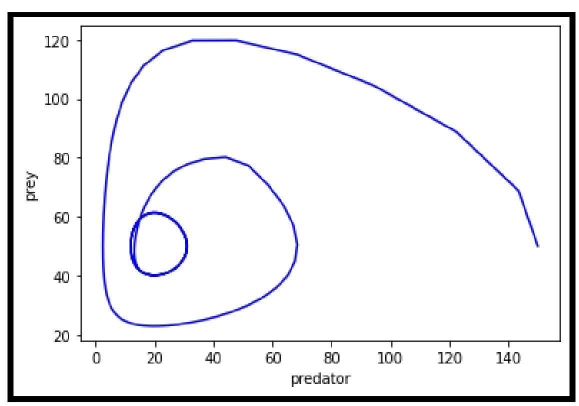


Section 2: With Pesticide

The second task of the assignment is to introduce a pesticide in order to control the population of the insects. This pesticide is distributed immediately if there is not already pesticide dispersed and if the population of the insects reaches about 100 times that of the amount of grass. Because the pesticide affects both species differently, two new factors are introduced: One for the amount at which the grass is affected by the pesticide (**λ**), and one for the amount at which the insects are affected by the pesticide (**ε**). After being multiplied by the amount of pesticide (**z**) and population of each corresponding species, each factor is subtracted at the end of the Lotka-Volterra equations. The resulting equations for change in prey and predator populations are: $dx/dt = \alpha x - \beta xy - \lambda zx$ and $dy/dt = \delta xy - \gamma y - \varepsilon zy$. Because the pesticide is meant to decrease the population of the insects, its effect on them is greater than its effect on the grass. While both the species are initialized with populations greater than zero so that their equations can oscillate normally, the pesticide does not oscillate. Instead, the amount of pesticide begins at zero, and only increases when the certain requirements, specified above, are met. The amount of pesticide then decreases at a constant rate until it dissipates completely.

While implementing the pesticide into the simulation, testing was done for the decision on when to deploy the pesticide. The original plan involved distributing the pesticide any time the insect population rose above an arbitrary amount. This quickly killed off both species, so the conditional statement was updated so that it would additionally only deploy when the previous batch of pesticide was exhausted. The following graphs correlate to this method, with the arbitrary limit on the insect population at 80:





As the blue spiral function in the graph above shows, this method of deploying pesticide is not a stable system. Subsequently, the conditional statement was changed yet again; Instead of distributing the pesticide solely based on the population of the insects, it will be distributed when the ratio between insect and grass population reaches a certain magnitude, which was chosen to be around 100:1. The following graphs correlate to this ratio that was determined to be the best overall method for simulating pesticide in the predator/prey dynamic: