Plot Exercise in TSRT04 (Ecology): Predator-Prey Dynamics

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This is one of the plot exercises in the course TSRT04. To pass the course you need to solve one of the plot exercises and present it on one of the lab sessions that offers examination. The examination will be in English, so please write your code and comments in that language. The exercise should be done in pairs, or individually. It is not allowed to share or show MATLAB code or notes to other students, since the exercise is part of the examination. It is, however, okay to discuss the exercise orally; for example, to share good advice!

1 Background

The interaction between predators and prey is a classic research topic in ecology. The basic hypothesis is that if there are plenty of prey (e.g., moose), then there will be plenty of food for the predators (e.g., wolves) which will grow in numbers. But as the number of predators grows larger, these will kill more and more prey, thus it makes sense that the number of prey will eventually begin to reduce. When the number of prey is too small to feed all the predators, then the predators will also reduce in numbers. Then the number of prey will increase again since there are not so many natural enemies left. And so the cycle starts all over again, at least according to the basic theory.

2 Description of the data set

In this exercise, we will study some real data from the national park of Isle Royale in USA: `http://www.isleroyalewolf.org`. The data set contains the number of moose and wolves that lived on the island in different years. The data set is available in the file `ecology.mat` that can be downloaded from Lisam.

Load the data set into MATLAB with the command

```
» load ecology
```

The years are specified in the vector `years`, while the number of animals are found in the matrix `animals`. The first column contains the number wolves (per year) and the second column contains the number of moose (per year).

3 Investigating and visualizing the data set

The purpose of this exercise is to investigate the data set by plotting the data in different ways. Follow the following steps:

1. Decide if you will write your code as a script, as different functions, or as a combination of both. If you write a script it might be good to begin with `clear` (which empties the workspace) and `close all` (which closes all open figures/graphs).

2. Plot the number of wolves and moose as a function of time. Everything in the same figure. Use `xlabel, ylabel, title`, and `legend` to describe what is shown in the figure. Use `xlim` to change the interval of the horizontal axis, so that it matches exactly the data.

3. As you probably have noticed, there are two orders of magnitude (100 times) more moose than wolves, which means that it is hard to see the exact numbers of wolves in the previous figure. This can be solved by having two different scales in the same figure. Use the command `plotyy`. Add some descriptive text as above, but skip `ylabel` and `xlim` (these are a bit complicated to use along with `plotyy`).

4. Use the command `subplot` to plot the same thing but in two different subfigures; for example, underneath each other. Use descriptive text in the same way as above.

5. What is the largest and smallest numbers of moose in the data set? Which year did these occur? Compute this using suitable MATLAB-commands. Mark these points with stars in one of your previous figures (you can use `plot` to do this). Then you do the same thing for the wolves and mark the values with rings. If there are multiple local minima on a curve, only mark the point with the smallest number of animals.

6. Think about how your figures would look like in a printout. There are two important things to keep in mind: 1) Use "strong" colors, such as black, red, and blue. Green and particularly yellow is often hard to see in printouts. 2) Make sure that it is possible to separate the curves also in a gray scale printouts. This requires different line styles (e.g., solid, dotted, dashdotted and dashed). You can use `plot` to select color and line style. Go through all figures that you created with `plot` and make sure that the curves are easy to distinguish (you don't have to change anything in the plot created with `plotyy` since this is complicated).

7. Save your figures, both in the MATLAB-format `.fig` and in the following four common image formats: `.jpg`, `.png`, `.pdf`, and `.eps`. Open the saved figures and compare the image qualities. Zoom in on each image and see which formats that always are sharp (so called vector graphics) and which ones become unsharp when zooming. Then you should import the figures into a word processing program (e.g., Word or Open Office). Which formats are most suitable for reports and similar use? Return to MATLAB and click-drag on the lower right corner of the figure to change its size and dimension on the screen. Save the file once more and check if your changes carried over to the saved file or not.

8. Preview how the figures will look like in gray scale. This can be done by choosing “Print Preview” in the menu “File” of a figure. You can switch between color and gray scale in the tab “Color”. If it is not possible to identify each curve in gray scale, you need to make necessary changes and make a new preview.

To pass this exercise you need to show and demonstrate the script and/or functions that you have created to solve the different tasks. You should have written comments in the code and made sure that the plots are self-explaining.

4 Further background on ecological theory

This section provides a short description of the underlying ecological theory and is, of course, not part of the examination in the MATLAB-course.

The dynamics between prey and predators are usually modeled by first-order differential equations:

$$\begin{aligned} \frac{\partial}{\partial x} x &= x(\alpha - \beta y) \\ \frac{\partial}{\partial y} y &= -y(\gamma - \delta x) \end{aligned} \tag{1}$$

where x is the number of prey and y is the number of predators. The parameters $\alpha, \beta, \gamma, \delta \geq 0$ describe the interactions.

The following is an interpretation of the equations in (1). If the prey has no enemies ($y = 0$), then they will grow faster and faster with time (exponentially). On the other hand, when the number of predators is too large, so that $\alpha - \beta y < 0$, then the derivative of x is negative and the number of prey will decrease.

The same type of tendency, but opposite, has been used to model the predators. If there are no prey to eat ($x = 0$), then the derivative of y will be negative and the number of predators will decrease steadily due to the lack of food. On the other hand, when there is a sufficient number of prey, so that $\delta x - \gamma > 0$, then the number of predators will increase with time.

Models of the type in (1) are simplified, since there is only two species that affect each other. In reality, there will be other animals, deceases, and weather conditions that affect the ecosystem. But simulations based on (1) gives similar behaviors as those observed for moose and wolves on Isle Royale. If you are interested, you can read more about the different factors that affected the dynamics in real data:

`http://www.isleroyalewolf.org/data/data/home.html`

5 Reference

Vucetich, JA and Peterson RO. 2012. *The population biology of Isle Royale wolves and moose: an overview.* URL: `http.//www.isleroyalewolf.org`