Assignment 2 - FIT3139

Due: Monday 11:55pm on Week 9
worth 25% of your final mark

April 12, 2024

This assignment covers content taught in weeks 4-6. You may use any of the following programming languages;

- Python
- MATLAB

For Parts 2-4, marks will be evenly spread between;

- Code correctness
- Quality of plots/ figures
- Quality of analysis

Part 1 requires no coding, so marks will simply be divided equally between

- Quality of plots/ figures
- Quality of analysis and problem of choice

General instructions

Over the last few weeks we have explored numerous ways of modeling dynamical systems. In this assignment we will put these new skills to use.

You will select a problem to explore for the duration of this assignment. You can choose any of the coupled dynamical systems we examined in class, including (but not limited to);

- The SIR model for epidemic spread
- The Lotka-Volterra predator-prey model
- The coupled model for Guerrilla warfare

You should consider a **question that can't be answered** by the current base model you choose. Then you need to propose at least one non-trivial, and novel extension to the base model, such that this extension allows you to answer your question (the extension is deemed novel if we haven't seen it anywhere in class). The question you propose should be about the system we're modelling not about the modelling technique itself. For example, we might ask the question:

"How do limited environmental resources affect population growth in a prepdator-prey system?"

And we might answer it with the Lokta-Volterra predator-prey model using the model extension that we saw in the week 6 applied class where we changed the growth rate in isolation of fish to be logistic.

The nature of your extension must satisfy at least one of the following criteria in bold:

- **Include an additional interaction between variables**, for example in SIR people can go from R back to S.
- **Include a new variable**, for example turning SIR into SEIR.
- **Change a model parameter into a function of one or more of the variables**, for example logistic growth in Lokta-Volterra.
- **Combine two or more extensions that we've seen in class but were studied independently of each other.**

The specific examples given above have been studied in class and are therefore not suitable for your own extension. The following types of extensions are also not suitable (not an exhaustive list):

- **Using an identical model to what we've seen in class but renaming the variables**. For example base Lokta-Volterra applied to "Foxes and Rabbits".
- **An extension that makes more sense to be implemented as an adjustment to one or more of the model parameters**, for example, in the week 6 applied class we saw social distancing in SIR represented by a reduction in β rather than a new varaible.

Students who fail to include a meaningful and novel extension to a dynamical system shown in class will have their grade capped at 60%. We encourage you to discuss with your tutors in class about the suitability of your question and extension.

Your report should be no more than 10 pages in length. Of course we want you to explore each question thouroughly, but if you find your report longer than 10 pages with a lot of plots and text, consider how you might communicate your findingds more succinctly. You can submit a jupyer notebook, or a *PDF and code* zip file.

Part 1 (6 marks) – Model selection

Present your question and state the base model you plan to extend. You should present and explain each of the equations, either in discrete or continuous time, that describe the base system and explain how these equations describe the dynamics. Describe your model extension and justify how it will answer your question. You should give a written explaination and present the updated equations for your extended model. Clearly state any assumptions you make in your model.

You can use a flow chart (if it's applicable to your model) or other visual aid in your response.

Part 2 (6 marks) - Discrete time analysis

Now that you have a coupled dynamical system set out, lets try modeling it.

Express your dynamical system in the form of difference equations, and then study the behaviour. Do so for a variety of initial conditions and model parameters.

Plot and explain your results. Discuss how your results illuminate the question posed in Part 1.

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Part 3 (7 marks) - Continuous time analysis

Let's see what happens if we move to continous time now. Express your system as a set of differential equations and, once again, simulate the behaviour of your system.

Do so for; * multiple initial conditions * multiple sets of model parameters * at least two diferential equation solvers, including an RK2 implementation that should be included in this submission.

Plot and explain your results, and be sure to point out any differences between discrete and continuous time that you notice. Discuss how your results illuminate the question posed in Part 1.

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Part 4 (6 marks) - Steady state analysis

Some dynamical systems will eventually converge to a steady state, where the rate of change for each variable is 0. For both, discrete and continuous time, discuss the steady states and how they relate to the systems behaviour.

Does the model have any steady states? If so, where are they located? How stable are they? Why? Discuss how your results illuminate the question posed in Part 1.

If your model is too involved to meaningfully produce steady state analysis and cobwebbing diagrams, feel free to make some simplifications to your model for this task.

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