Module 1 – Modeling infectious disease Lab

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Introduction

This lab will apply the SIR model in the context of a zombie epidemic as presented in the recent article published by a University of Ottawa researcher and his students [1]. Their compartment model divides the population into three classes: susceptible (S), zombie (Z), and removed (R). Susceptibles may die from natural causes (at a rate of δ) or from a zombie attack. The susceptible population can only increase through new births (at a rate of Π). They may become infected through contact with zombies. Zombies themselves can only die by being defeated by a human (for some examples of how this may be done see *Zombieland*). The zombie population can increase through infection of susceptibles *and* by resurrection of the dead. The links between these classes are shown graphically in figure 1 and as differential equations below.
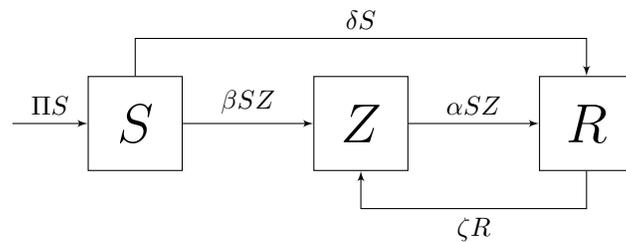

Figure 1: A basic zombie epidemic model

$$\frac{dS}{dt} = \Pi S - \delta S - \beta SZ$$

$$\frac{dZ}{dt} = \beta SZ - \alpha SZ + \zeta R$$

$$\frac{dR}{dt} = \delta S + \alpha SZ - \zeta R$$

Task (A). *Download both the code template for the Zombie lab and the jmathplot librarie from the web site $https://compute.dawsoncollege.qc.ca/$. Extract the archive in your H: drive and open ZombiesStudentVersion.java. Change the settings in your editor to display line numbers.*

1. *Try to compile the code. You should get two error messages caused by two classic mistakes. Find them and fix them.*

2. *Not all mistakes will be found by the compiler. With the parameters given, the number of susceptibles should decrease to less than one thousand in about 8.9 days. That is not what you will get if you run the code and check the output data. You will see a weird variation in the number of susceptibles and a negative number of zombies!? This is due to a minor error in Euler's method. Fix it.*

3. *Considering the plot of S, Z and R versus t, after roughly how many days is the zombie population greater than the human population?*

4. *How does the future of humanity look?*

When you reach this point, show your results to a teacher.

Task (B). *Make a copy of your code and give it a different name. Now, let's make some refinements to our model.*

To start, the timescale of a zombie epidemic appears to be short and it is probably reasonable to ignore birth and natural death rates altogether.

1. *Modify the graphical representation on the previous page to account for these assumptions and correct the differential equations.*

2. *Re-run the simulation. Does ignoring birth and death rates have an important effect?*

As the model stands, individuals go directly from being susceptible to active zombies without any incubation period. We should include some exposure period during which an infected individual is not yet a zombie. To do so, we will need a new class of individuals, the latent (L), as shown if figure 2.

3. *Assuming the incubation period is half a day, what is the appropriate value for the parameter κ?*

4. *Modify your code and rerun it with the same parameters as before.*

5. *Considering the plot of S, Z and R versus t, what effect does the incubation period have on the evolution of the epidemic?*

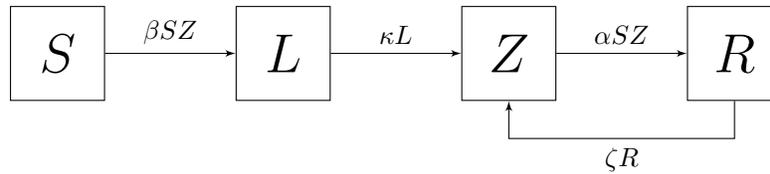When you reach this point, show your results to a teacher.

Figure 2: Updated zombie model

Task (C). *There is one major problem with the model: since it assumes that everyone in the removed class can be resurrected as a zombie, humans have no chance for long-term survival. Propose a more realistic model wherein zombies can actually die for good and where some proactive steps are taken by humanity to preserve itself (things like quarantine, vaccination, mass eradication, and so on).*

*In a **short** report (should be less then two pages, figures included):*

- *Explain your compartment model and provide a graphical representation.*

- *Modify your code and explore the required values for any new parameters in order for humanity to have a chance at survival.*

- *Present a plot of S, Z and any other relevant categories versus t and summarize the parameters required for survival.*

If you want to plot different categories than S, Z, and R, you can do so by modifying the `printf` statements to print different data to the output file and then copy-paste the data in a spreadsheet to generate your graphs.

If you feel more adventurous you can even get live plots of your new categories by adding an array in the portion of the code scanning the data file and then by modifying the `plot.addLinePlot` statements to print whater three quantities you want.

Due date: One week from today at the beginning of class

References

[1] Munz, P., Hudea, I., Imad, J. and Smith?, R.J. *When zombies attack!: Mathematical modelling of an outbreak of zombie infection.* Infectious Disease Modelling Research Progress, pp 133-150, 2009.