CMPLXSYS 530 Lab4

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All codes and original figures are in Github:
`https://github.com/ShirlynWY/CMPLXSYS_LABS.git`
Project specs: `https://epimath.github.io/cscs-530-materials/Labs/Lab4.html`

1 Sensitivity analysis of a predator-prey model

(a) In general, when the number of rabbits increase, the number of foxes will increase with some lag. Similarly, when the number of rabbits decrease, the number of foxes decrease with some lag. From the visualization of the agent based modeling, I noticed that neither rabbits nor foxes are distributed uniformly in the space. In fact, the prey population move in swarms and the predator population follow them in space.

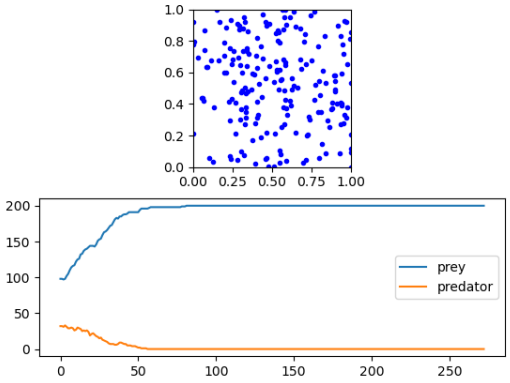
I ran 4 simulations with different parameters. Other than the parameters indicated in the figures, all other parameters are at default value. I observed a few outcomes:

(1) Foxes go to extinction and rabbits grow to carrying capacity.

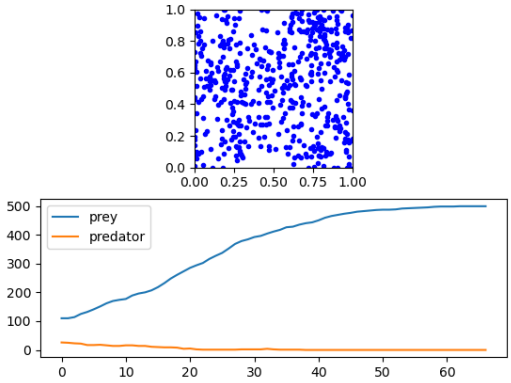
(2) Both rabbits and foxes go to extinction

(3) Number of rabbits and number of foxes oscillates out-of-phase (as illustrated by Fig1d)

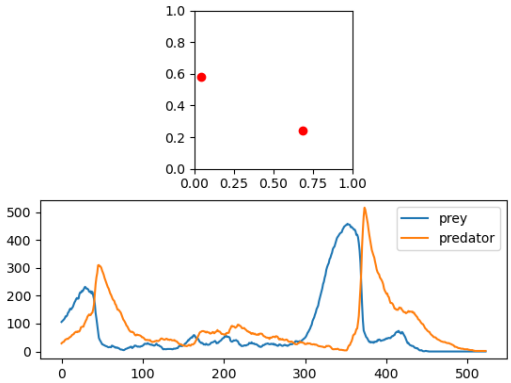
The graph of the third scenario has some similarities to the graph of the ODE model in Sayama 4.6. Both populations oscillate out-of-phase, although the graph of the ABM doesn't have a smooth sinusoidal shape like in the ODE model. Moreover, the amplitude of oscillation clearly decreases in the ODE model but this trend is not clear in the ABM model.



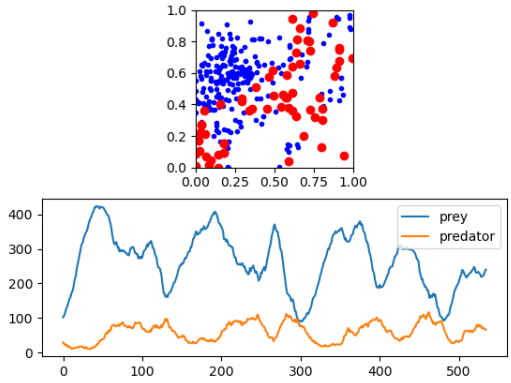
(a) nr = 200, dr = 1, df = 0.1, rf = 0.5



(b) nr = 500, dr = 0.6, df = 0.2, rf = 0.5



(c) nr = 500, dr = 1, df = 0.05, rf = 0.8



(d) nr = 500, dr = 1, df = 0.1, rf = 0.5

Figure 1: Predator and prey simulations with varying parameters

(b) Fig2 shows 5 simulations with default parameters. Brightness of the line indicates which simulation (i.e. the brightest red and brightest blue lines were from the same simulation, etc.). I think the trajectories look similar in the first 30 days and apparent variations in the trajectories in different simulations appear after that. Overall, the patterns are similar to what I described in 1(a). Number of rabbits and number of foxes oscillates out-of-phase. And if foxes go to extinction, rabbits grow to carrying capacity.

(c) In Fig3a, I varied the carrying capacity of rabbits and observed the final number of each animal. Because this model is stochastic, I run 6 simulations for each carrying capacity and took the mean final number of animals. We can see that when carrying capacity increases from 200 to 300, the foxes go to extinction and rabbits grow to carrying capacity. As carrying capacity increases from 300 to 800, the mean final number of foxes increase and. The mean final number of rabbits has an increasing trend with some dips in the middle.

I believe the number of rabbits should also increase as carrying capacity increases. The dips in the plot might be caused by only taking into account the final number of rabbits. The

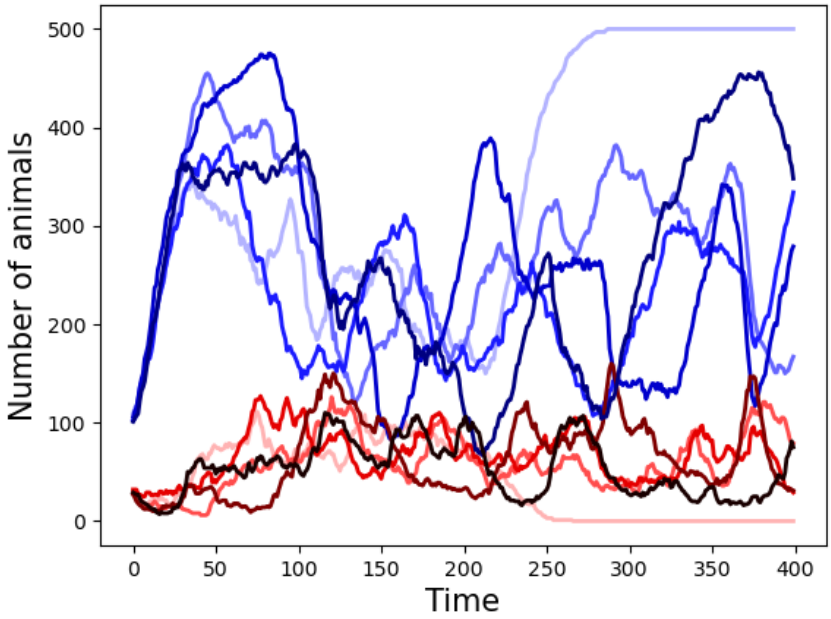
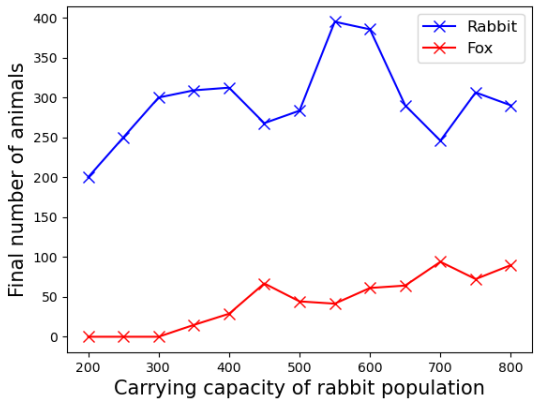
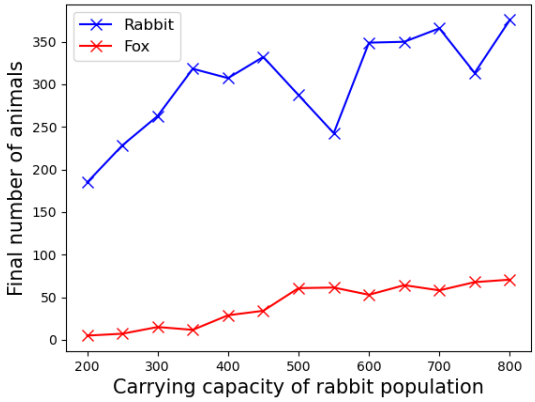


Figure 2: 5 runs of the predator prey model with the default parameters. Blue lines indicate rabbits (prey) and red lines indicate foxes (predators). Brightness of the line indicates which simulation (i.e. the brightest red and brightest blue lines were from the same simulation, etc.).

rabbit and fox populations can be oscillating. The final value may be on a peak or trough of the oscillation. The dip in the rabbit curve in my plot might have happened because the final reading was near the trough. Therefore, I ran the simulations again and took the average of the last 50 time steps for each simulation. And I again took the average across 6 simulations for each carrying capacity. The rising trend of the both populations became slightly clearer in 3b.



(a) Mean final number of animals vs carrying capacity of rabbits



(b) Mean of the populations in the last 50 time steps

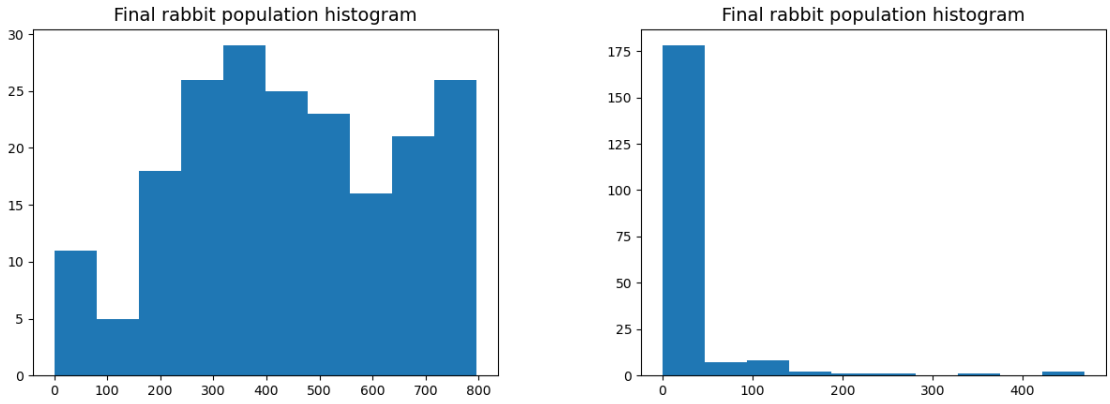
Figure 3: Predator and prey simulations with varying parameters

(d) In this part, we explored the sensitivity of the model behavior to 4 parameters:

- nr, the carrying capacity for rabbits
- dr, the death probability for rabbits when they encounter a fox
- df, the death probability for foxes when they have no food
- rf, the reproduction probability for foxes if there is food (rabbits) nearby

We took the bounds for nr to be from 200 to 800, and the other parameters we will take to be between 0 and 1. I sampled 100 parameter sets using Latin hypercube sampling, and run the model twice for each parameter set. Fig4 shows the histogram of the rabbit and fox populations in the 200 simulations. Fig5 shows the scatter plot of final fox population vs. final rabbit population.

From the plots, clearly in most of the simulations, foxes go to extinction and rabbits grow to carrying capacity.



(a) Rabbit population

(b) Fox population

Figure 4: Histograms of final populations

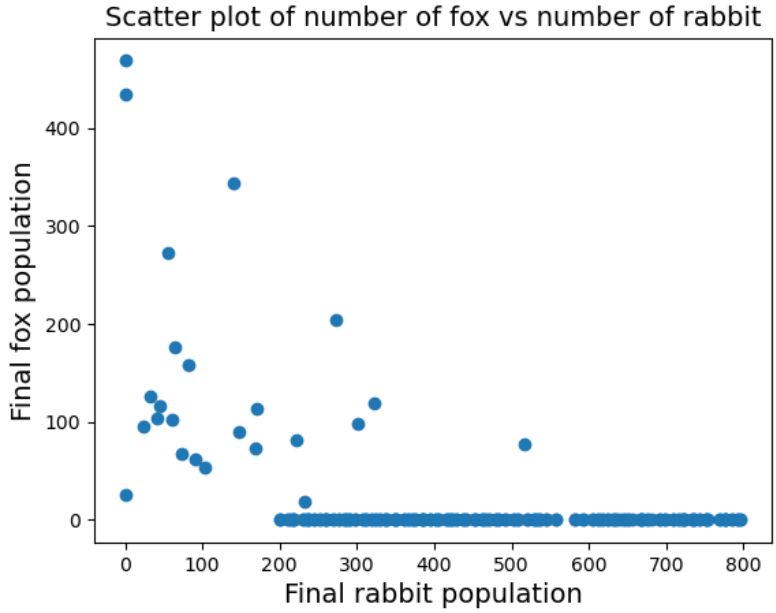
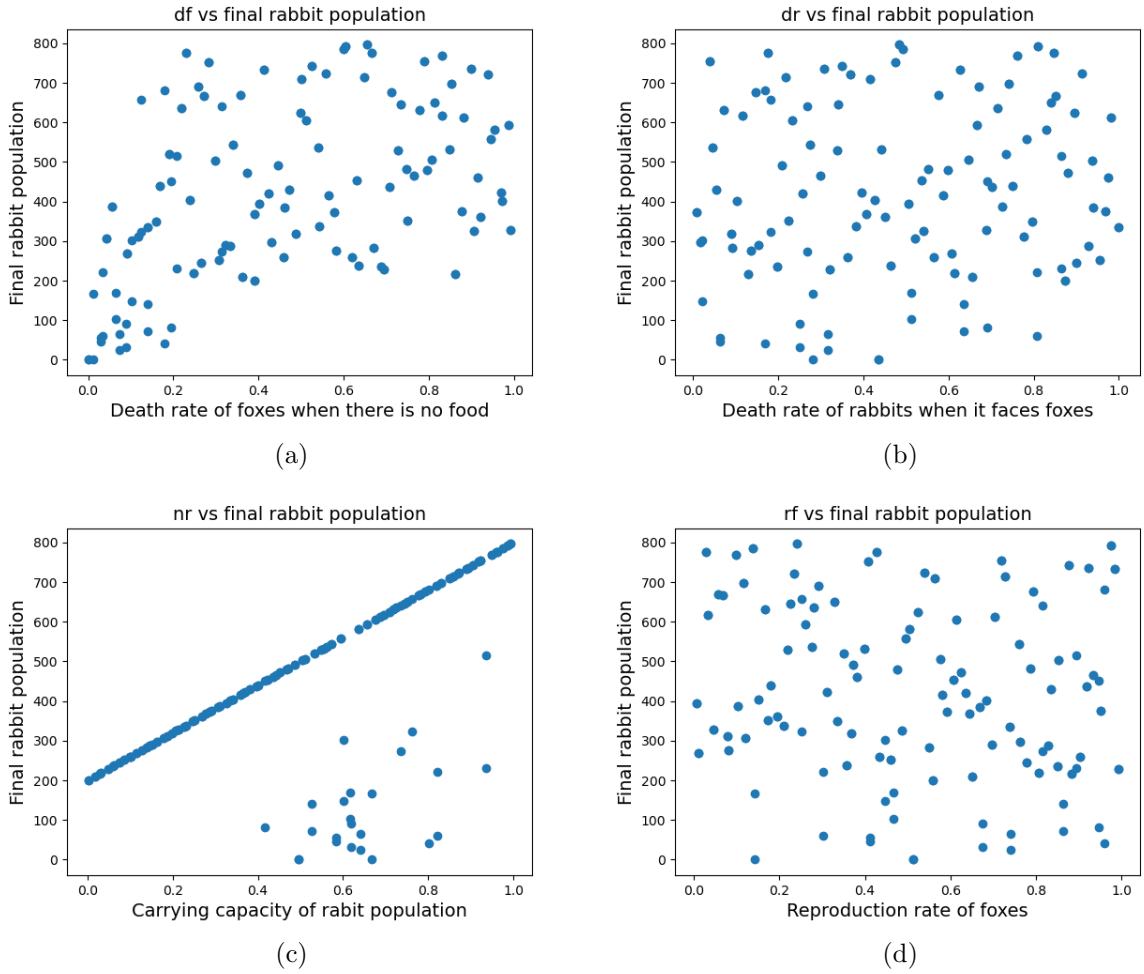


Figure 5: Scater plot of final number of foxes vs final number of rabbits

(e) Fig6 show the scatter plots of each parameter vs final rabbit population size. From subfigure(c), the final rabbit population clearly shares a linear relationship with carrying capacity. This makes sense because in most of the simulations, the foxes die out and the rabbits grow to carrying capacity. From subfigure(a), the final rabbit population is sensitive to the death rate of foxes when there is no food. The oucome seems insensitive to the death rate of rabbits when facing foxes and the reproduction rates of foxes. Fig7 show the scatter plots of each parameter vs final fox population size. The outcome doesn't seem to be sensitive

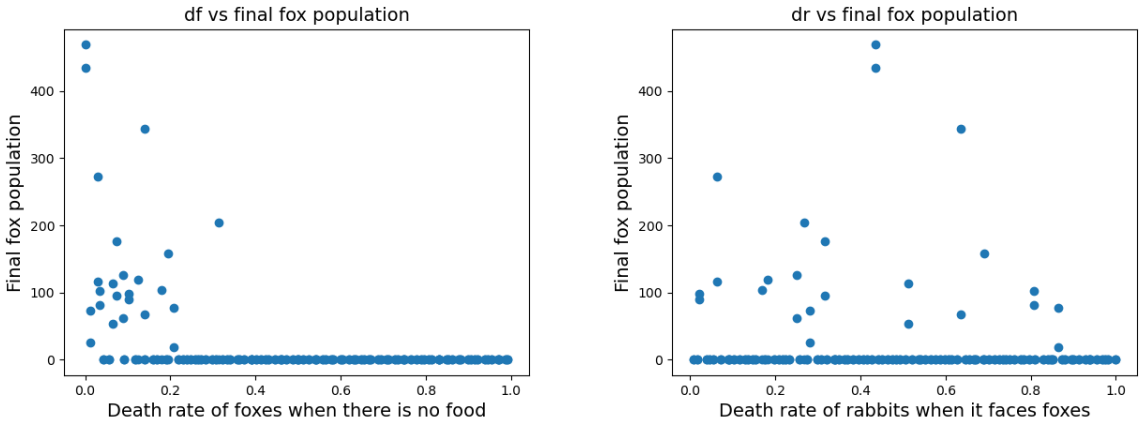


(a) (b) (c) (d)

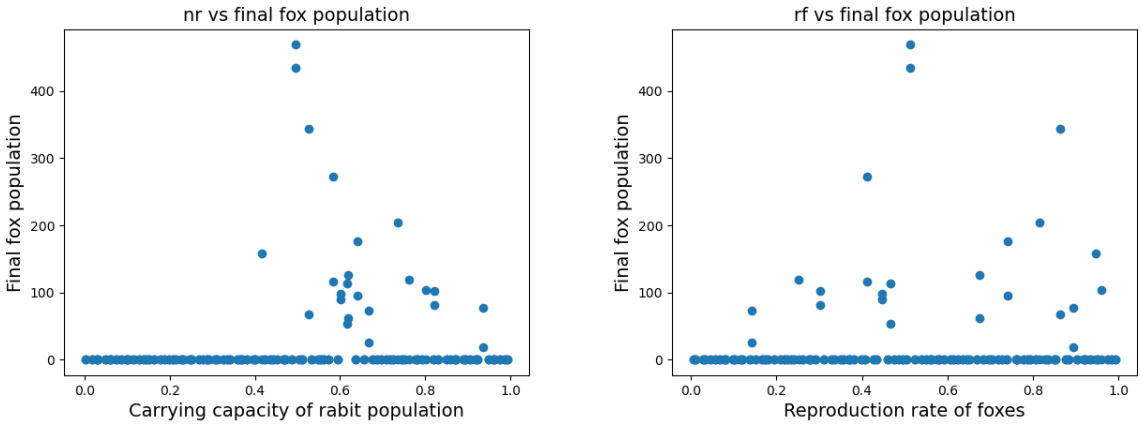
Figure 6: Scatter plots of each parameter vs final rabbit population

to any of the 4 parameters chosen, because in most simulations, foxes just go to extinction.

Fig8 shows the heatmaps. Subfigures(a) and (b) show how the final rabbit population changes for varying pairs parameters. (a) shows combinations of death rate of foxes when there is no food and death rate of rabbits when facing foxes. (b) shows combinations of death rate of fox and carrying capacity of rabbit population. Subfigues (c) and (d) are similar to (a) and (b), except that the outcome is final fox population.

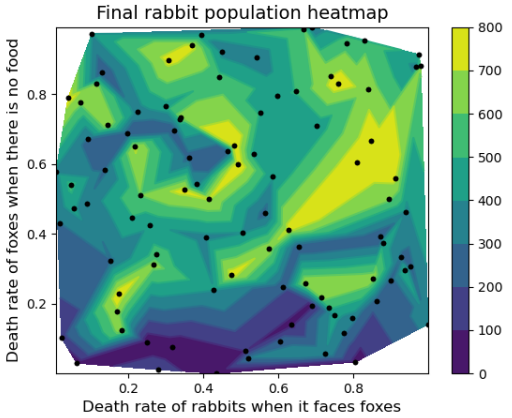


(a) (b)

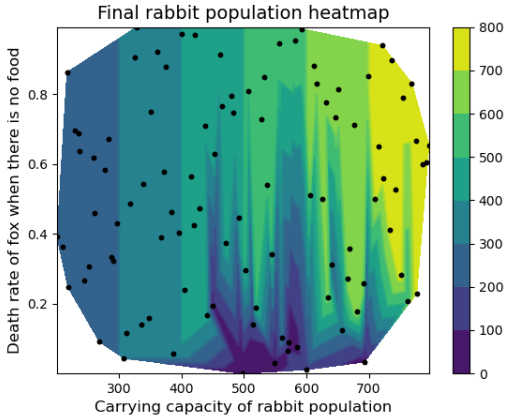


(c) (d)

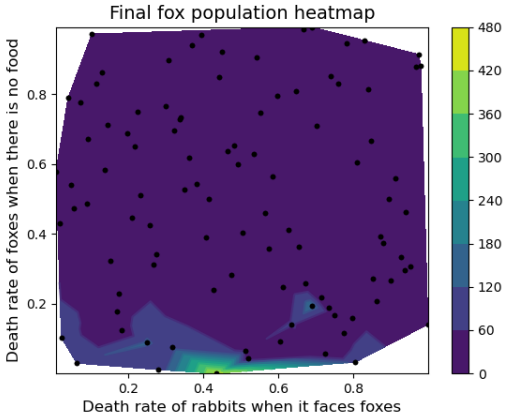
Figure 7: Scatter plots of each parameter vs final fox population



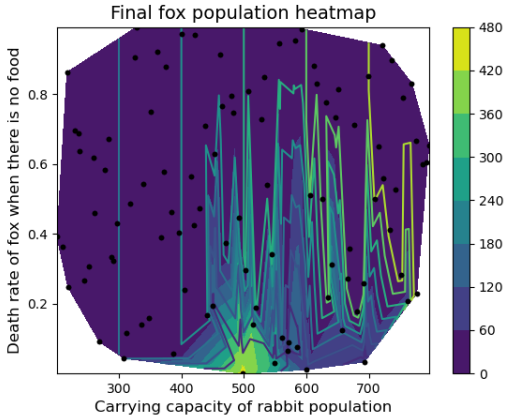
(a)



(b)



(c)



(d)

Figure 8