Guided Study Program in System Dynamics
System Dynamics in Education Project
System Dynamics Group
MIT Sloan School of Management[1]

Assignment #10

Assigned on: Friday, November 13, 1998

Due by: Monday, November 23, 1998
                  12:00 PM (Noon)[2]
                  WE WILL REVIEW THE RESPONSES ON MONDAY
                  AFTERNOONS, BOSTON TIME.
                  LATE SUBMISSIONS WILL NOT RECEIVE FULL
                  ATTENTION.

Please email assignment solutions, questions, or comments to:
gsp@sysdyn.mit.edu
Save solutions with the filename XYZ-S10.doc
(where XYZ are your initials)

Reading Assignment:

Please refer to Road Maps 3: A Guide to Learning System Dynamics (D-4503-4) and read the following:
- *Study Notes in System Dynamics*,[3] by Michael Goodman, Chapters 4 and 5

Then refer to Road Maps 5: A Guide to Learning System Dynamics (D-4505-4) and read the following paper from Road Maps 5:
- Beginner Modeling Exercises Section 5: Mental simulation of Combining Feedbacks in First-Order Systems, by Laughton Stanley and Helen Zhu (D-4593-1)

Please download and read the following paper from http://sysdyn.mit.edu/gsp98/
- Mistakes and Misunderstandings: Time Constants and Decay Fractions, by Mila Getmansky (D-4679)

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[2] The deadline is in United States Eastern Time, equivalent to Greenwich Mean Time minus 4 hours during US daylight savings time, and Greenwich Mean Time minus 5 hours for the rest of the year.

[3] Goodman, Michael R., 1974. *Study Notes in System Dynamics*, Waltham, MA: Pegasus Communications. 388 pp.

Exercises:

1. Study Notes in System Dynamics, Chapter 4: S-Shaped Growth Structure

Please note that even though the equations of the "S-shaped growth structure" shown in Figure 4-3 of the Study Notes generate S-shaped growth, the structure was not designed to represent any real-world system. When modeling a system that exhibits S-shaped growth, such as the rat population system in Figure 4-10, you could make a scatter plot of the level values vs. the rate values, and you would obtain a graph similar to the "Rate value" variable in Figure 4-3, or to the graphs shown in Figure 4-6. In fact, Figure 4-12 shows such a scatter plot. In general, we will not use level vs. rate plots but instead will concentrate on graphs depicting the level and the rate behaviors over time.

A. Please build the rat population model shown in Figure 4-10. Make sure that the table function for "infant survival multiplier" has a dimensionless input. To do this, you will need to define several additional variables, not shown in Figure 4-10.

- the "NORMAL RAT DENSITY" equals 0.0025 rats per squared foot.
- the "density ratio" is the ratio of "population density" to the "NORMAL RAT DENSITY"
- the "infant survival lookup" is a table function that looks just like the table function in Figure 4-11, but the scale of the input, the "density ratio", ranges from 0 to 10
- the "infant survival multiplier" is the "infant survival lookup" function of the "density ratio": infant survival multiplier = infant survival lookup(density ratio)
- the "NORMAL RAT FERTILITY" equals 0.4 rats per female per month

Notice that the "NORMAL RAT DENSITY" was chosen somewhat arbitrarily to equal 0.0025 rats per square foot. From the table function in Figure 4-11, one can see that the "infant survival multiplier" is equal to 1 for values of the "population density" less than and equal to 0.0025 rats per square foot. Hence, up to this density, the "rat birth rate" will equal the "NORMAL RAT FERTILITY" multiplied by the "female rat population."

With the above equations, your model should be dimensionally consistent, and your lookup function will have normalized inputs and outputs.

In your assignment solutions document, please include the model diagram, a graph of the lookup function, documented equations, and a graph of model behavior.

B. As mentioned in the *Study Notes*, this model accounts for only one density effect. The "rat death rate" is also likely to be increased because of a higher density of rats. Modify the model built in part A to include another table function, the "effect of density on rat lifetime." In your assignment solutions document, please include the new model diagram, documented equations, and a graph of the new lookup function.

C. Before simulating the model, draw a reference mode for the stock "Rat Population." Then simulate the model. Does the model generate the behavior you expected? Why or

why not? Explain any differences in behavior between this model and the original model from part A. In your assignment solutions document, include graphs of the behavior of the stock and the two flows.

2. Study Notes in System Dynamics, Chapter 5:   Review of Simple Structures: Industrial Land-Use Model

Follow the chapter and build the complete industrial land-use model as shown in Figure 5-20. In your assignment solutions document, include the model diagram, documented equations, a graph of the "land availability multiplier" table function, and a graph of model behavior. Remember to modify the model from Figure 5-20 so that it contains all the variables required to formulate a lookup function in Vensim PLE, as well as all the "normal" values of variables.

3. Beginner Modeling Exercises Section 5: Mental simulation of Combining Feedbacks in First-Order Systems

After reading this paper and doing all the included exercises, answer the following question:

This paper presented a first-order system that produces S-shaped behavior, where initial exponential growth is hindered by constraints on the system. Think of a system you are familiar with that exhibits S-shaped growth. Explain clearly the positive and negative feedback loops that are driving the system behavior and why you believe there will be a shift in loop dominance.

4. Mistakes and Misunderstandings: Time Constants and Decay Fractions

Read this paper carefully. You do not have to answer any questions for this paper but if you can think of an instance when you made the same mistake, feel free to share with us the lesson you learned.