Guided Study Program in System Dynamics

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

Assignment #29

Assigned on: Friday, June 11, 1999

Due by: Monday, June 28, 1999
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-S29.doc
(where XYZ are your initials)

Reading Assignment:

Please download and read the following paper from http://sysdyn.mit.edu/gsp98/ :

- Second-Order Systems, by Leslie A. Martin (D-4731)

Also, please read the following:

- *Introduction to Computer Simulation,*[3] by Nancy Roberts et al.: Chapter 10

[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] Roberts, Nancy, David Andersen, Ralph Deal, Michael Garet, and William Shaffer, 1983. *Introduction to Computer Simulation: A System Dynamics Approach.* Portland, OR: Productivity Press. 562 pp.

Exercises:

<u>1. Second-Order Systems</u>

A. Refer to the scenarios that generate asymptotic behavior in Figures 6, 13, and 14 of the paper. Can you think of any real world systems in which a carefully balanced positive feedback loop produces stabilizing behavior?

B. The scenarios in this paper vary the sign of the parameters, and the sign and magnitude of the initial values of the stocks. What would happen to the different scenarios if one were to also vary the magnitude of the parameters? Support your answer with examples and graphs of model behavior.

<u>2. Modeling Exercise: Waste Disposal</u>

Chapter 10 of Introduction to Computer Simulation leads you through the conceptualization stage with the Solid-Waste Disposal system.

Step 1: Conceptualization

Read Chapter 10 of Introduction to Computer Simulation. In your assignment solutions document, include your answers to Exercises 1-4.

Step 2: Getting Started

To make the exercise more relevant and interesting to each of you, choose a specific product for the model you are going to build. You should have enough background knowledge of the product whose disposal you wish to model to be able to estimate the demand for the product, its lifetime (how long it is used before it gets thrown away), and the time it takes to disintegrate. Identify the key variables to be included in the model.

Step 3: Model Structure

A. Start by identifying the stocks in the system. Which variables are stocks, and how are they connected?
Hint: You do not need to build a stock of recycled materials. Instead, recognize that recycling simply returns the product to a state it was previously in.

B. Link the stocks with appropriate flows.

C. Add any relevant auxiliary variables or constants to complete the model structure.
Hint 1: Use the idea of coverage to obtain the desired number of products from the demand for products.
Hint 2: A goal-gap structure determines production.

Step 4: Equations and Parameter Values

Fill in values and equations for the model components. You will need to estimate many of the parameters and initial values based on your knowledge of the product. In your assignment solutions document, include the model diagram and documented equations.

Step 5: Simulating the model

Once the model is complete, make sure that all units are correct. Then simulate the model. In your assignment solutions document, include graph of the model behavior. Did you observe the behavior that you had predicted in the conceptualization assignment? Why does the model generate the behavior observed?

Step 6: Sensitivity Analysis

A. How would the system behavior change if the government passed legislation offering incentives for people to recycle, raising the percentage of products that is recycled? Simulate the model under these conditions. In your assignment solutions document, include graphs of model behavior, and discuss the effect of more recycling.

B. Technology improves and the product now lasts much longer. What are the effects of altering the product lifetime? Simulate the model under these conditions. In your assignment solutions document, include graphs of model behavior, and discuss the effect of the technology improvement on the waste disposal system.

3. Independent Modeling Exercise

"I live on the forth floor of a dormitory that, unfortunately, has no elevators. Before, when I came home at night I always ran out of breath before I reached the top of the stairs. I've decided to exercise more. I found out that after I get into the habit of jogging 8 hours a week—at a leisurely pace, believe me—I am able to climb the 80 stairs that lead up to my room without wheezing.

"When I arrived at school in September, I was only able to make it up 20 stairs before I started to wheeze. At the time I was running 2 hours a week. Upset with my lousy fitness, I decided to start exercising more by running more often. It took me about a week to become motivated to change my exercising habits. My body is even slower to react; after changing my exercising habits, I didn't feel the improvement in climbing stairs for another six weeks. However, I persevered, and now I am finally able to reach my room without coughing and panting. I feel like a new woman."

Leslie, on exercising

A. Use Leslie's testimony to conceptualize and formulate an exercise model to answer the following questions she once had:

- What will happen to my physical fitness over the next year?
- What will happen to the number of hours I spend each week exercising?

In your assignment solutions document, include the model diagram, documented equations, and graphs of the behavior you observe. Explain the dynamic behavior of the model in one or two paragraphs.
Hint: Assume that Leslie's fitness level (measured by the number of steps she can climb without wheezing) improves only by running, not by climbing stairs.

B. How would Leslie's physical fitness have evolved if she had responded faster to her pathetic condition? How would Leslie's physical fitness have evolved had she been slower to respond? Why? Justify your answer with graphs of model behavior and an explanation of the dynamics underlying the model.
Hint: Leslie's response can be measured in two ways. One way is how quickly she changes her exercise habits in response to the realization of her pathetic condition. Another way is how quickly her body responds to the new exercise habits.

4. Independent Modeling Exercise

"One of my friends bought me a guitar for Christmas. I have a difficult time tuning the guitar before I sit down to play. I pluck a string, observe the pitch, and then rotate the appropriate nut, thereby changing the tension in the string. Then I listen to the difference between the new pitch and the pitch I want and continue to adjust the nut accordingly. It takes me a second to adjust the knob, but ten seconds to observe the discrepancy in pitch, because I am actually sampling the pitch at discrete intervals.

"Well, the pitch of the note is tabulated in terms of the frequency of the sound wave created by the vibration of the guitar string after I pluck it. A middle G, for example, is 196 hertz (Gs played at higher octaves have higher frequencies). A middle D is approximately 146.8 hertz."

Harriet, on guitars

A. Use the above description to conceptualize and formulate a guitar tuning model that demonstrates how the pitch of Harriet's guitar changes when she attempts to tune a string from a D to a G. In your assignment solutions document, include the model diagram, documented equations, and graphs of the behavior that you observe. Explain the dynamic behavior of the model in one or two paragraphs.

B. How would the behavior of the model change if Harriet were to sample the pitch less frequently? How would the behavior of the model change if Harriet developed a better ear, shortening the time it takes her to observe the discrepancy in pitch? Why? Justify your answer with graphs of model behavior and an explanation of the dynamics underlying the model.