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

Assignment #20

Assigned on: Friday, March 12, 1999

Due by: Monday, March 29, 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-S20.doc
(where XYZ are your initials)

Reading Assignment:

Please download and read the following paper from http://sysdyn.mit.edu/gsp98/
- Mistakes and Misunderstandings: DT Error, by Lucia Breierova (D-4695)

Please read the following:
- *Principles of Systems*,[3] by Jay W. Forrester, Section 2.3

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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] Forrester, Jay W., 1968. *Principles of Systems*, (2nd. ed.). Waltham, MA: Pegasus Communications. 391 pp.

D-4756-1

Exercises:

1. Mistakes and Misunderstandings: DT Error

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 the lesson gained with us.

2. Understanding Oscillatory Systems

This is the fourth in a series of exercises designed to help your understanding of oscillatory systems. Build the following model in Vensim PLE and then complete the exercises. Make sure that the time step is smaller than 0.0625 (or small enough that the value of DT no longer has a substantial effect on the result of the simulation). The time horizon over which you simulate the model should be at least 16 units of time.
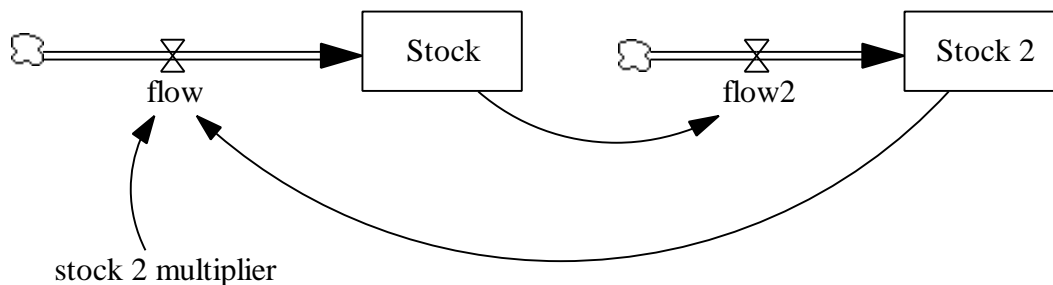
flow = Stock 2 * stock 2 multiplier

flow2 = Stock

Stock = INTEG (flow, –1)

Stock 2 = INTEG (flow2, 0)

stock 2 multiplier = –1

Notice that "flow2" is not an outflow from "Stock"; only the information about the value of "Stock" is used as the input to "flow2." Similarly, the information about the value of "Stock2" is used as the input to "flow."

A. Simulate the model.[4] In your assignment solutions document, include graphs of the behavior of the "flow," "Stock," and "Stock2." Explain the behavior that you observe and relate it to your conclusions from the previous exercises on oscillatory systems.

B. Create a new dataset and simulate the model with initial value of "Stock" equal to 0 and initial value of "Stock 2" equal to –1. In your assignment solutions document, include graphs of the behavior of the "flow," "Stock," and "Stock2" in this simulation. Explain the behavior that you observe and compare the simulation to that from part A.

C. Repeat part B with initial value of "Stock" equal to –2 and initial value of "Stock 2" equal to 0.

D. Repeat part B with initial value of "Stock" equal to –0.5 and initial value of "Stock 2" equal to 0.

E. What conclusions can you make about the behavior of an oscillatory system as the initial value of "Stock" and "Stock 2" changes?

F. Repeat part B with initial value of "Stock" equal to –1, initial value of "Stock 2" equal to 0, and "stock 2 multiplier" equal to –2.

G. Repeat part B with initial value of "Stock" equal to –1, initial value of "Stock 2" equal to 0, and "stock 2 multiplier" equal to –0.5.

H. What conclusions can you make about the behavior of an oscillatory system as the "stock 2 multiplier" changes?

3. Principles of Systems

Please read section 2.3 of *Principles of Systems* and do the workbook exercises for this section (located at the end of the book). The material in this chapter is very important and you should make sure you understand it. Please let us know if you have any questions. You do not need to submit anything for this reading assignment.

4. Modeling Exercise

Helen is addicted. Every day Helen visits a local coffeehouse, a subsidiary of a famous café chain with a French name that no one can pronounce correctly. There she buys tall steaming cups of Java brew coffee that she slowly drinks over the course of the day to fight off the drowsiness caused by many sleepless nights spent programming in the

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[4] When simulating this model, you might notice that the oscillations are slightly expanding. This is due to the nature of the computation process used in Vensim PLE. To correct the problem, try repeatedly reducing the time step by a half until you believe the results are no longer significantly affected by the DT value.

computer room. In this exercise we will study the effects of Helen's addiction to caffeine.

Initially Helen has 50 Mg of caffeine in her body. Every day she usually consumes 200 Mg of caffeine. If she is feeling particularly drowsy, however, she will consume more. Helen feels the effect of the caffeine for an average of 6 hours before her body disposes of it.

A. From the above description, create a stock-and-flow diagram of the level of caffeine in Helen's body. For now, define the effect of drowsiness on caffeine consumption in such a way that the rate of caffeine consumption will equal Helen's usual consumption. In your assignment solutions document, include the model diagram and documented equations.

B. Draw a reference mode for the behavior of the stock. Simulate the model over a period of ten days. In your assignment solutions document, include a graph of the behavior of the level of caffeine in Helen's body.

C. Helen is having a hectic semester because of a difficult class that she is taking: the Laboratory in Software Engineering (coincidentally, she programs in Java). She now consumes twice her usual amount of coffee. Draw a reference mode for the new behavior of the stock. Simulate the model. In your assignment solutions document, include a graph of the model behavior in this scenario. Did the model generate the behavior that you predicted?

Over time, Helen has developed a tolerance for caffeine. Helen's body expects a certain level of caffeine. If the level of caffeine in Helen's body changes, her body will adapt over time and begin to expect a new level of caffeine. After about five days, Helen's body will develop a tolerance for her new caffeine habits.

D. From the above description, add a stock and a flow to the model to account for the amount of caffeine Helen's body expects at any point in time.[5] Set the initial value of the stock equal to the initial value of the level of caffeine in Helen's body.   In your assignment solutions document, include the modified model diagram and documented equations.

E. Draw reference modes over sixty days for the behavior of expected level of caffeine in Helen's body under the normal workload scenario (when Helen drinks her normal amount of coffee). Simulate the model. In your assignment solutions document, include a graph of model behavior. Did the model generate the behavior that you predicted? Why or why not?

F. Draw reference modes over sixty days for the behavior of expected level of caffeine in Helen's body under the heavy workload scenario (when Helen drinks twice her usual

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[5] Formulate the exponential smoothing process without using the SMOOTH function that Vensim PLE provides.

amount of coffee). Simulate the model. In your assignment solutions document, include a graph of model behavior in this scenario. Did the model generate the behavior that you predicted? Why or why not?

Helen drinks coffee to ward off drowsiness. Normally, Helen yawns approximately ten times a day. When she has a relatively high level of caffeine, she is less drowsy; she yawns less frequently. When she has a relatively low level of caffeine, she feels drowsy and yawns more frequently. Specifically, when her body has one and a half times the expected level of caffeine, she only yawns once or twice a day. When her body has half the expected level of caffeine, she yawns approximately eighteen times a day.

G. Add auxiliary variables and lookup function to your model to account for Helen's drowsiness.
Hint: drowsiness has units of yawns/day.

The drowsier Helen feels, the more caffeine she consumes. For example, when she feels twice as drowsy as usual, she drinks twice and a half as much coffee. If she feels half as drowsy, she drinks one third as much coffee. If she feels four times as drowsy, she will consume five times as much coffee. She will never consume more then five times her usual amount of coffee, however, because if she does, she will start shaking and be unable to type.

H. Add a second lookup function to the model and close the feedback loop. In your assignment solutions document, include the modified model diagram, documented equations, and graphs of the lookup functions. How many feedback loops are now in the model? Describe each feedback loop.

I. Draw reference modes for the behavior of the two stocks under the normal workload scenario. Simulate the model. In your assignment solutions document, include graphs of the model behavior. Does the model produce the behavior that you expected? Why or why not?

J. Now that the drowsiness loop is in place, the second scenario can be implemented more realistically. Create a parameter called "effect of extra workload on drowsiness." The parameter will have no effect until the tenth day, when the final project is assigned and the extra workload doubles Helen's current drowsiness. Draw reference modes for the behavior of the two stocks in the model in this scenario. Simulate the model. In your assignment solutions document, include the modified model diagram, documented equations, and graphs of the model behavior. Does the model produce the behavior that you expected? Why or why not?

K. After graduation, Helen decides to go camping in the mountains for a few weeks with her friends. She forgets to bring coffee with her and is unable to find any as she hikes up the rocky trails. Create a parameter called "effect of camping trip on consumption." Draw reference modes for the two stocks in the model and the variable drowsiness. Simulate the model over a period of ten days. Assume that Helen leaves Boston to go

camping on the second day. In your assignment solutions document, include the modified model diagram, documented equations, and graphs of model behavior. Does the model produce the behavior that you expected? Why or why not?[6]

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[6] For this scenario, make sure to change the "Effect of extra workload on drowsiness" back to 1, to study one scenario at a time. Obviously, when Helen is on her camping trip, she is not subject to her increased workload.