Guided Study Program in System Dynamics

System Dynamics in Education Project
System Dynamics Group
MIT Sloan School of Management

Assignment #6

Reading Assignment:

Please refer to Road Maps 3: A Guide to Learning System Dynamics (D-4503-4) and read the following:

- *Introduction to Computer Simulation*,[2] by Nancy Roberts, et al.: Chapter 15
- *Study Notes in System Dynamics*,[3] by Michael Goodman: Sections 3.10 and 3.11, and Exercises 6 and 7

Then refer to Road Maps 7: A Guide to Learning System Dynamics (D-4507-1) and read the following paper from Road Maps 7:

- Mistakes and Misunderstandings: Examining Dimensional Inconsistency, by Michael Shayne Gary (D-4452-1)

[2] 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.
[3] Goodman, Michael R., 1974. *Study Notes in System Dynamics*, Portland, OR: Productivity Press. 388 pp.

Exercises:

1. Introduction to Computer Simulation

Please read Chapter 15 of Introduction to Computer Simulation by Nancy Roberts. This reading will reinforce your understanding of positive and negative feedback. There are no exercises assigned on the reading, but you should be sure you are comfortable with all of the concepts covered before proceeding.

2. Study Notes in System Dynamics (Sections 3.10 and 3.11, Exercises 6 and 7)

A. Read section 3.10. Build and simulate the inventory control model on page 52. In your assignment solutions document, include the model diagram, documented equations, and a graph of model behavior.

B. The inventory control model contains a feedback loop linking the stock to the inflow. Explain intuitively why the system exhibits negative-feedback behavior instead of positive-feedback behavior.

C. What is the half-life of the inventory? Give a mathematical answer and compare it with results from graphs of model behavior.

D. Do Exercise 6 on page 183 by hand, then verify your results by simulation. In your assignment solutions document, include graphs of model behavior for questions E6.4 to E6.7.

E. Read section 3.11. Examine the liquid cooling model on page 55. Using mental simulation, find the half-life of the coffee heat (use parameter values listed in the equations).

F. Using mental simulation, determine how much time elapses before coffee temperature and room temperature are approximately equal. Explain your answer.

G. Build and simulate the liquid cooling model. In your assignment solutions document, include the model diagram, documented equations, and graphs of model behavior. Were your answers for parts E and F correct? Why or why not?

H. Do Exercise 7 on page 193 and check your answers with the solutions on page 203. You do not need to submit anything for this part. Please let us know, however, if you had problems with any of the exercises.

3. Mistakes and Misunderstandings: Examining Dimensional Inconsistency

Please read this paper carefully. You do not need to submit anything for this reading. The lesson you should learn from it is to always use the units checking feature in Vensim PLE!

4. Independent Modeling Exercise: Population Demographics

This exercise will develop a population dynamics model and use the model to test several different scenarios.

A. Imagine a small town in rural Kansas with 3000 inhabitants. The population is initially evenly distributed between children aged 0 to 20 years, child-bearing adults aged 20 to 45 years, and seniors aged 45 to 75 years (assume that no one lives past the age of 75). In its marital relations, the town is quite typical; when two people are married, they have, on average, 2 children together. You are interested in studying how the demographics of the small town will change over time. You can assume for the purposes of this model that all deaths are related to old age.

The model will contain the elements listed below. Identify each element as either stock, flow, or constant, and label its units. For each stock, determine its inflows and outflows.

- maturing
- years as a child-bearing adult
- children
- number of child-bearing couples
- deaths
- years as a child
- aging
- births
- seniors
- babies per couple
- child-bearing adults
- adults per couple
- years as a senior
- total population (sum of the populations of all age groups)

B. Using Vensim PLE, combine the elements to represent the structure of the system. In your assignment solutions document, please include the model diagram.
Hint: One time constant will be used twice in the model to define two different rates.

C. Using the description of the system provided above, define the equations for all model elements. In your assignment solutions document, please include the documented equations.

Hint: If there are N people in an age group and they remain in that age group for M years, then N/M people leave the age group each year.

D. Before you simulate the model, draw reference modes for all stocks in the model. You do not need to include these in your assignment solutions document, but you do need to draw them in order to be able to answer the next question.

E. Simulate the model over 100 years. Make sure to use a DT that is less than one-eighth of the shortest time constant in the model. In your assignment solutions document, include graphs of the behavior of all stocks and of total population. Did the model generate the behavior you predicted? Why or why not?

F. Imagine a small agricultural village in central China. Again, a population of 3000 people is initially evenly distributed between children aged 0 to 20 years, child-bearing adults aged 20 to 45 years, and seniors aged 45 to 75 years. In this village, however, each couple only has one child.

Change the original population model to represent the new scenario. What happens to the population distribution now? Draw reference modes for each stock. Then simulate the model over 100 years. In your assignment solutions document, include graphs of the behavior of all stocks and of total population. Did the model generate the behavior you predicted? Why or why not?

G. Imagine a small village in Bangladesh. A population of 3000 people is also initially evenly distributed between children aged 0 to 20 years, child-bearing adults aged 20 to 45 years, and seniors aged 45 to 75 years. In this village, however, each couple has four children.

Change the original population model to represent the new scenario. What happens to the population distribution now? Draw reference modes for each stock. Then simulate the model over 100 years. In your assignment solutions document, include graphs of the behavior of all stocks and of total population. Did the model generate the behavior you predicted? Why or why not? Can you foresee any problems in Bangladesh that would be caused by the behavior you observed?

H. Humanitarian envoys attempt to convince the couples in the small village in Bangladesh to reduce the number of children they have. Assume that for some reason the villagers decide to comply with the envoys' request. Starting in year 50, couples go from having 4 children to having 2 children each.

Change the original population model to represent the new scenario. What happens to the population distribution now? Draw reference modes for each stock. Then simulate the model over 100 years. In your assignment solutions document, include graphs of the behavior of all stocks and of total population. Did the model generate the behavior you predicted? Why or why not? How could a system dynamics perspective help in proposing recommendations for developing countries with high birth rates?