Maryland Virtual High School
Instructional Activity

Student/Teacher Mentor Program in Modeling and Simulation

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Course: High School Computer Science elective in Modeling and Simulation

Last Modified: December 6, 1995

The preparation of this report was supported by the
Gordon Stanley Brown Fund
administered by the System Dynamics Society.

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Student/Teacher Mentor Program

Half of the one-semester Modeling and Simulation course taught at Montgomery Blair High School is devoted to system dynamics as expressed in STELLA. Although the upperclassmen in the course have used STELLA during their freshman year to model systems in physics, they have not had the opportunity to explore it in depth. In this course, not only do they have the opportunity to see a wide range of examples of STELLA models, they also are given the freedom to choose a system of interest to them for which to develop a model. See Appendix 1 for a sample of a unit test.

First, we study causal-loop diagrams as presented in Introduction to Computer Simulation by Nancy Roberts, et al. We translate some of our diagrams to STELLA, exploring appropriate built-in functions. We also study the numerical integration methods, Euler and Runge-Kutta, comparing their results using different step sizes. This leads us to the recognition that the modeling of discrete events versus continuous ones requires different integration methods. For example, if a student is modeling the action of a savings account earning interest quarterly, Euler's method with a step size of 0.25 must be used. On the other hand, the modeling of a physical or chemical reaction which changes continuously over time requires the use of Runge-Kutta with a small step size. See Appendix 2 for a sample worksheet.

Once the students have designed and mastered a variety of models, they are ready for their independent projects. They are required to choose a problem for which a model would be a useful teaching tool. Then they must find a teacher who would like to use this model in classroom instruction. This requires them to explain STELLA to the teacher and to work with the teacher to choose an appropriate problem. At a faculty meeting before making the assignment in class, I announce that the students will be approaching their teachers so that they are not taken by surprise. The students then submit a written proposal to me describing the system to be modeled, the resources to be used for data and information collection, and the name of the teacher-mentor. I reserve the right to approve or change the topic if I feel it is either too easy or too difficult for the student. See Appendix 3 for the project description form and sample project ideas.

The students then have two weeks of class time to work on their models. During the design of their model, they are required to meet with their mentor to verify the causal relationships in their model. When they have completed their models, they write a report in which they state the problem, give the background information needed to understand the concepts behind the model, explain the model itself and verify the correctness of the model's results. They then invite their mentor to their presentation in which they explain the model to their classmates and demonstrate the results. If the mentor is unavailable during the classroom presentation, the student must schedule a lunch-time or after-school time to present to the mentor. All audience members, classmates, teacher and mentor, participate in the evaluation process. See Appendix 4 for the presentation evaluation form. Appendix 5 contains the evaluation form used by the mentor to critique the overall quality of the student's work.

The most difficult part of this project is model verification. If the student chooses a topic which has known mathematical relationships, it is fairly straightforward to insert given values into the model and verify that the results match those expected mathematically. On the other hand, if the data regarding the system is limited to trends and observations, it is more challenging to validate the results. It is easy to tell when a model is clearly wrong, but a model with errors in it can appear to give logical results.

Since models vary in difficulty, some students are not going to be successful in their attempts to validate their models. This leads to a dilemma. Should all students be assigned systems for which the validation will be absolute? Or, should more challenging systems be allowed so that the students experience the difficulties of real-world modeling? I choose the latter within reason. Usually the more able students gravitate toward more challenging problems, and I encourage them in their efforts. I believe that they will learn more from a system that frustrates them than from a system that is transparent to them. Ideally, the student will seek and get help from the mentor; and most do. Unfortunately, the reality of busy schedules and the unfamiliarity of the mentor with STELLA impacts the amount of assistance the mentor can give.

The student/teacher mentor program benefits both parties. The student gains a better understanding of both STELLA and the subject matter chosen as a result of having to work through a model independently. The teacher sees a new way to present material to a class. Those teachers whose models are flawed may ask to have another student attack the problem the next year or may elect to learn STELLA and fix the model themselves. As a result of this process, teachers who never heard of system dynamics consider using STELLA models as an instructional tool in their classrooms.

APPENDIX 1

MODELING AND SIMULATION
STELLA Unit Test
100 points

NAME ______________________________
September 26, 1994

1. In a simplified squirrel model, the annual birth rate of a squirrel population is 3 babies per female squirrel. The annual death rate is 1/3 of the squirrel population. If the squirrel population in 1988 was 900, calculate the populations for the next two years using Euler's Method. Show your work. (10)

2. For each of the following models, choose the appropriate computation method and the appropriate dt. Then justify your answers. (12)

   A) Euler   B) Runge-Kutta 2   C) Runge-Kutta 4

   1) dt = 1   2) dt = 0.5   3) dt = 0.25   4) dt = 0.125

   ___________ a) Compounding interest quarterly

   ___________ b) Compounding interest continuously

   ___________ c) Movement of a spring

3. Consider the following scenario: (20)

   (This problem is a modification of a problem found in Chapter 18, pp. 337-352, of Introduction to Computer Simulation by Nancy Roberts, et al.)

   The Sahel has been the home of nomads for centuries. The nomads have survived by adapting to the difficult conditions under which they must live. They moved their animals from grazing spot to grazing spot with each season. Because of the limited amount of food and water available to the animals, the herds never got very large. Due to the severe climate, disease, and poor diet, the same was true of the nomad population. Moreover, every twenty or thirty years a severe drought would kill many animals and people, keeping their numbers from growing too large.

In recent years, the United Nations decided to try to improve the life of these nomads. They vaccinated the nomads against smallpox and measles, and they brought malaria and sleeping sickness under control. They also brought animal diseases under control. Using modern machinery, deep wells were drilled which reached the supply of underground water. With more water and fewer diseases, the animal population grew. However, the animals soon ate or trampled the little grass available. A six-year drought further decimated the grass. The animals began to die of starvation, and many nomads starved. The United Nations had a more severe problem in the Sahel after their help than before.

a) Draw a causal loop diagram illustrating the stable system described in the first paragraph. Sign every arrow and every closed feedback loop.

b) Add to your diagram (in another color) the factors described in the second paragraph, including signed arrows and feedback loops.

4. STELLA Model: (58)

On the disk provided, set up the model for the problem described below. Tomorrow you will receive data to use in equations for the model. You are on your honor NOT to discuss this problem NOR to seek help in any way.

The Kaibab Plateau is a large, flat area of land located on the northern rim of the Grand Canyon. It has an area of about 800,000 acres, and it is the natural home of rabbits, deer, mountain lions, wolves, coyotes, and bobcats. In 1906, President Theodore Roosevelt created the Grand Canyon National Game Preserve, which included the Kaibab Plateau. Deer hunting was prohibited, and a bounty was established to encourage the hunting of mountain lions and other natural deer predators. During the period from 1906 to 1931, nearly 800 mountain lions were trapped or shot. As a result of the extermination of the Kaibab mountain lions and other natural enemies of the deer, the deer population began to grow quite rapidly - from 4000 in 1906 to 100,000 in 1924.

As the deer population grew, Forest Service officials and other observers began to warn that the deer would exhaust the food supply on the plateau. Over the winters of 1924 and 1925, nearly 60 percent of the deer population on the plateau died of starvation. The deer population continued to decline over the next 15 years, finally stabilizing at 10,000 in 1939.

Imagine that you were an official of the National Forest Service in 1940, and you were interested in the fate of the deer population on the Kaibab plateau. You have decided to build a model with a time frame of 1906 to 1956 so that you can predict the future deer population. You have access to data regarding the following:

1. The annual birth rate of deer
2. The grazing needs of a deer (acres of vegetation)
3. The average life span of a deer
4. The annual food consumption per deer
5. The annual food production
6. The initial number of food units available
7. The initial number of mountain lions
8. The annual birth rate for mountain lions
9. The average life span of a mountain lion
10. The number of deer killed per year per mountain lion
11. The years in which the bounty was in force

12. The number of mountain lions killed per year by hunters during the years without a bounty.
13. The number of mountain lions killed per year by hunters during the years with a bounty.

Finish your model with the following information.

1. Each doe has one birth per year.
2. Each deer grazes on 8 acres of vegetation per year.
3. The average life span for deer is 5 years with adequate grazing, 4 years with 60% of the grazing, and 2 years with 40% of the grazing.
4. When there are 8 or more acres of vegetation available per deer, each deer consumes one unit of food (equivalent to 4 acres). When there are 4 acres of vegetation per deer, each deer consumes 0.8 units. As the acres of vegetation per deer fall below 4, each deer consumes almost all of the available food.
5. The rate of vegetation growth equals the difference between the acreage capacity of 800,000 acres and the current vegetation level in acres, divided by the time for vegetation regeneration. When the vegetation level is zero, the time for regeneration is 40 years. When the vegetation level is one-half the capacity, the regeneration time is 5 years, and when the vegetation level is near capacity, the regeneration time is one year.
6. The initial number of food units is 200,000.
7. The initial number of mountain lions = 200.
8. Each female mountain lion has one birth per year.
9. The average life span for mountain lions is 5 years.
10. The number of deer killed depends on the deer density per acre.
    At 0.005 deer per acre, each male lion can kill 6 deer per year.
    At 0.025 deer per acre, each male lion can kill 60 deer per year.
    At 0.05 deer per acre, each male lion can kill 120 deer per year.
11. The bounty was in force from 1906 to 1931.
12. Hunters killed 10% of the mountain lions each year there was no bounty.
13. Hunters killed 40% of the mountain lions each year there was a bounty.

Turn in your disk as well as a printout of the graph showing your deer and mountain lion populations.

APPENDIX 2

MODELING AND SIMULATION
SHORT LAB - 50 points
DUE DATE - Monday, Sept. 13

Using the STELLA model of acceleration, velocity and displacement developed in class, design and execute an experiment to determine the accuracy of the three numerical integration methods when stepsize and acceleration are changed.

GIVEN: $v_0 = 0$ and $x_0 = 0$
StartTime = 0
StopTime = 24

STEPSIZE: Start with a stepsize of 1 and gradually lower the size to find the relationship between stepsize and accuracy for each method. Find the stepsize at which truncation error appears to invalidate the results.

ACCELERATION: Experiment with acceleration functions which are constant, linear, quadratic, logarithmic, exponential, and sinusoidal.

RESULTS: Compare and contrast Euler's Method, Runge-Kutta 2, and Runge-Kutta 4 with respect to the effects that different stepsizes and acceleration functions have upon the accuracy of the results. Answer the question - which is the best method to use? Back up your conclusions with data, but choose the means of expressing the data which will be the most meaningful to your reader. Turn in a word-processed report with accompanying print-outs of your STELLA runs. You may include diagram, equation, table and graph windows. But, choose wisely because your grade will be lowered if you supply unnecessary print-outs.

APPENDIX 3

MODELING AND SIMULATION
INDEPENDENT PROJECT - 100 points

Project Description:

In conjunction with a Blair teacher, choose a topic which can be illustrated with a time–driven simulation. In most cases, there will be multiple levels of difficulty represented in your models. Your models must be verifiable through the use of equations or real data. The models should be seen as a teaching tool for the topic in question.

Written Product: You will prepare a word-processed report detailing

- the background information needed for your model
- the data/equations used to verify your model
- the instructional uses of your model
- the experimentation permitted by your model
- a bibliography
- an appendix of print-outs of diagram, equation, and graph windows for your models

Oral Product: You will make a 15-20 minute presentation to the class, showing

- the background of your model
- the results of your model

Due Date: Friday, October 21

Presentations: October 24 - 28

TOPICS CHOSEN BY STUDENT/TEACHER TEAMS

Social Sciences
1. Model the factors which influence the level of unemployment in the USA.
2. Model the factors which influenced the migration of African-Americans from the South to the North after the Civil War.

Marine Biology
1. Model the effects of pollution on the oxygen level of a stream.
2. Model the factors which caused the decline of submerged aquatic vegetation in the Chesapeake Bay.
3. Model the progression of an ecosystem from beach to maritime forest.
4. Model the American oyster population in the Chesapeake Bay.

Biology
1. Model the levels of ATP in a cell as the cell goes through the metabolic process.
2. Model the catabolism of food molecules.
3. Model the process of yeast fermentation.

Genetics
1. Model the Hardey-Weinberg genetic laws of equilibrium.

Physics
1. Model a piston-and cylinder to demonstrate the concepts of reversibility and conservation of energy.
2. Model the movement of a pendulum as it is affected by various conditions.
3. Model the photoelectric effect.
4. Model the Michaelson-Morley Experiment to demonstrate the theory of special relativity.
5. Model the motion of an object on an inclined plane.
6. Model two-dimensional projectile motion with fluid resistance.

Earth Science/Astronomy
1. Model the effect of the moon, sun, earth system on the tides on the earth.
2. Model the earth-moon-sun system in order to predict solar eclipses.
3. Model the force of impact of a comet hitting the Earth.

Mathematics
1. Model the spread of an infectious disease.

Chemistry
1. Model the process of titration of Nitric Acid and Ammonia
2. Model the combustion of gasoline under varying conditions.
3. Model the Haber Process to determine the conditions which yield the maximum profit.

APPENDIX 4

MODELING AND SIMULATION
PRESENTATION EVALUATION FORM

Rank each of the categories from 1 to 10. Include comments.

Scorer: ____

Presenter and Topic: ______________________________

Categories:

A. Definition of the problem ___________
What is the purpose of the model?

B. Overview of the model ___________
Are the stocks and flows logical?
Do they reflect an accurate model of the cause and effect relationships?

C. Acquisition of data ___________
What were the sources of data?
How was the data interpreted?

D. Accuracy of model behavior ___________
How was the model evaluated for accuracy?

E. Suggestions for further testing and improvement of the model ___________

APPENDIX 5

MODELING AND SIMULATION
CRITIQUE OF INDEPENDENT PROJECT
December 20, 1994

Due Date: January 13, 1995

To: ________________________________ (Teacher Name)
From: Susan Ragan

Re: ________________________________ (Student Name)

During the first quarter, the student named above selected you as the teacher for whom he/she wanted to develop a STELLA model. At this time, I would like you to meet with the student in order to evaluate his/her work. The purpose of this evaluation is two-fold:

1) To give you an opportunity to see the project and to determine if it is usable in your classroom as a teaching tool.
2) To determine whether or not the student achieved the goals of the project.

Please rate the project in the following areas. Please add comments. I will use your ratings and comments to assign the student a score out of 30 points.

1. The scientific/mathematical complexity of the topic being modeled

a basic concept	moderately complex	very complex

2. The clarity with which the student explained the model to you

I understood everything	I got the basic idea of the model	I was confused by the explanation

3. The level of understanding of the concepts being modeled as exhibited by the student

The student understands very well	The student has a general understanding	The student has major gaps in his/her understanding

4. The degree to which the model accurately represents the concepts being illustrated

no flaws	a few flaws, but easily fixed	major errors, needs a different approach

5. The degree to which the student followed your directions

I gave no specific directions	The student followed my general guidelines	The student worked with me very closely

6 . Possible uses of this model

I see no use in my classroom	With minor changes, this would be useful	I could use this model in its present state

Comments:

PLEASE RETURN THIS TO SUSAN RAGAN'S MAILBOX IN THE MAIN OFFICE OR IN THE MAGNET OFFICE. THANK YOU FOR YOUR TIME.