Modeling and Simulation

CSE Written Qualifying Exam

Spring 2021

Instructions

- Please answer three of the following four questions. All questions are graded on a scale of 10. If you answer all four, all answers will be graded and the three lowest scores will be used in computing your total.
- Please write clearly and concisely, explain your reasoning, and show all work. Points will be awarded for clarity as well as correctness.

Problem 1

Consider a parallel discrete-event simulator that uses the Time Warp algorithm on a class of applications with the following property: when the computation rolls back and re-executes events, it is often—but not always—the case that the same events (messages) will be scheduled during the re-execution phase as were scheduled in the original execution.

Describe a scheme for Time Warp that can exploit this property to execute more efficiently than simply re-executing. Then give pseudocode for a Time Warp executive that implements your scheme.

Problem 2

A large tree farm has come to you asking for advice on how to set a policy that can be used to guide their tree harvesting for the foreseeable future. They have brought you three potential modeling approaches they are considering using, all based on a discrete-time logistic model of population growth:

$$T_{n+1} = T_n + rT_n\left(1 - \frac{T_n}{K}\right), \tag{1}$$

where T_n represents the number of trees in the population after n years, r is the growth rate of the tree population (without a sign restriction), and $K > 0$ is the carrying capacity. You should assume that new trees will occur only through population growth (that is, only the harvesting mechanism removes trees), that the trees are generally healthy and not under any external environmental stresses (drought, insect infestation, etc.), and that there is an initial population of trees $T_0 > 0$.

The differences in the modeling approaches are based on how to incorporate a harvesting term, which will reduce the population.

Option 1.

$$T_{n+1} = T_n + rT_n \left(1 - \frac{T_n}{K}\right) - hT_n, \tag{2}$$

where $h \geq 0$ is a constant. Here, logistic growth is based on the previous year's tree population and trees are separately removed at a rate proportional to the previous year's tree population.

Option 2.

$$T_{n+1} = T_n + r\left(T_n - hT_n\right)\left(1 - \frac{T_n - hT_n}{K}\right), \tag{3}$$

where $h \geq 0$ is a constant. In this case, the harvesting is incorporated into the tree population terms in the logistic growth component.

Option 3.

$$T_{n+1} = T_n + r\left(T_n - hT_n\right)\left(1 - \frac{T_n}{K}\right) - hT_n, \tag{4}$$

where $h \geq 0$ is a constant. This option is similar to Option 1 except that the logistic growth rate incorporates the harvesting term.

Your task. Your job is to provide feedback about the models.

1. What **biologically meaningful long-term behaviors** are available for each model? (In other words, assuming that the three constants r, K, and h do not change, what can realistically happen to the population after "many" years?)

2. Under which conditions will these long-term behaviors occur? Explain briefly (a sentence or two) why these conditions are or are not reasonable.

3. Comment on which model(s) you think is (are) most appropriate. (It is not acceptable to say all are equally good; you need to express some opinion and provide a justification for your opinion.) You may wish to consider, for example, how you might expect the long-term behavior of the population to depend (or not depend) on each parameter and why.

Problem 3

You need to develop a strategy to evacuate a large coastal city (with a population in the millions or more) in an emergency situation, such as an incoming hurricane. The metric you are concerned with is the amount of time needed to completely evacuate the city. You are to develop a simulation model to evaluate alternate evacuation approaches. Describe the simulation model you would develop to attack this problem. What type of modeling approach would you use (queueing model, cellular automata, differential equations, etc.)? Justify you answer relative to alternate approaches. What are the key state variables and parameters used by the model? What data would you need to collect in order to create a credible model? How would you validate your model, given that performing an actual evacuation is not practical?

Problem 4

Consider a 1-D cellular automaton that evolves according to *local rule 110*, which means it maps each possible three bit values to a new bit according to the following table:

	0	1	2	3	4	5	6	7
Current state	000	001	010	011	100	101	110	111
Next state	0	1	1	1	0	1	1	0

(Reading the next-state bits from left-to-right, observe that $2^1 + 2^2 + 2^3 + 2^5 + 2^6 = 110$, hence the name of the rule.)

Furthermore, recall the fact that a NAND (not-and) gate is a *universal* logic operation in that all other logic primitive logic gate operations (and, or, not, exclusive-or) can be constructed from NAND plus constant bits. Using this fact, show that local rule 110 is also universal.