**Exercises**

**1.1** Using the resources at (http://www.informs-sim.org/wscpapers.html) find an application of simulation to a real system and discuss why simulation was important to the analysis.

There are many possible answers to this question. Expect applications in manufacturing, health care, logistics, military, etc. to be found. In general, simulation facilitates the modeling of complex systems with the fidelity required to make good decisions.

**1.2** Read the paper: Balci, O. (1998) “Verification, Validation, and Accreditation”, in the *Proceedings of the 1998 Winter Simulation Conference*, D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, eds., pp. 41-48, IEEE Piscataway New York. (http://www.informs-cs.org/wsc98papers/006.PDF) and discuss the difference between verification and validation. Why is the verification and validation of a simulation model important?

Answers may vary. Verification ensures that the model is working as intended. Validation ensures that the model represents the system as intended. Without verification and validation, the simulation should not be used.

**1.3** Customers arrive to a gas station with two pumps. Each pump can reasonably accommodate a total of two cars. If all the space for the cars is full, potential customers will balk (leave without getting gas). What measures of performance will be useful in evaluating the effectiveness of the gas station? Describe how you would collect the inter-arrival and service times of the customers necessary to simulate this system.

Potential performance measures include:

* Utilization of the pumps
* Expected number of cars in queue
* Expected waiting time in queue
* Expected number of cars that balk per unit time
* Probability that a car will balk

The point of this question is to have the student contemplate some of the difficulties in actually collecting real data for a simulation.

Collecting the inter-arrival times will be complicated by potential non-stationary arrival patterns. That is, the rate of arrival may vary by the time of day and by day of the week, and potentially the season (summer may have higher rates than winter). If possible a computerized method can be devised (e.g. a car counter based on pulse wire, or a camera system). The pump may allow the collection of the start of pumping and the stopping of pumping or alternatively the number of pump uses, but this does not yield the true arrival rate. It only yields those that use the pump. Thus, those that arrive and balk would be missing. If the times are collected by hand, then enough samples during each possible operating period of the station would need to be obtained. If the rate varied by time of day, then multiple days are required. For example, if Fridays are suspected to be different from other days, then we need to observer multiple Fridays in the sample. If the rate is suspected to vary by season, then it would best to have multiple observations of the seasonal period! Wow that is a lot of time spent collecting data. Alternatively, the computerized pump usage might be able to yield non-stationary adjustment factors. If possible, it is best to get the actual times of arrivals, so that the inter-arrival distribution can be examined. If only counts of arrivals are available, then a Poisson or non-homogeneous Poisson might be used for the arrival process. See chapter 3 for more on this. To collect the service times, you need to clearly demark when service begins and when it ends. For example, does service start when the patron gets out of the car or when the patron lifts the pump handle? A computerized capture of the pump start and stop times may be available, but this does not include other portions of the service time. In addition, the service time might vary significantly if the patron pays with cash, check, credit, etc. These and many other issues should be considered in collecting data for even this simple system.

**1.4** Classify the systems as either being discrete or continuous:

a) Electrical Capacitor (You are interested in modeling the amount of current in a  capacitor at any time t).

b) On-line gaming system. (You are interested in modeling the number of people  playing Halo 4 at any time t.)

c) An airport. (You are interested in modeling the percentage of flights that depart  late on any given day).

a) continuous

b) discrete

c) discrete

**1.5** Classify the systems as either being discrete or continuous:

a) Parking lot

b) Level of gas in Fayetteville shale deposit

c) Printed circuit board manufacturing facility

a) discrete (tracking number of cars in lot, etc) If tracking the movement of the vehicles it could be considered continuous

b) continuous

c) discrete

**1.6** Classify the systems as either being discrete or continuous:

* a)  Elevator system (You are interested in modeling the number of people waiting  on each floor and traveling within the elevators.)
* b)  Judicial system (You are interested in modeling the number of cases waiting for  trial.)
* c)  The in-air flight path of an airplane as it moves from an origin to a destination.

a) discrete

b) discrete

c) continuous

**1.7** What is model conceptualization? Give an example of something that might be produced during model conceptualization.

See pages 10-13 of the text. Model conceptualization is the phase of the simulation methodology that focuses on understanding the system and representing the system narratively, pictorially, and logically in order to facilitate the translation of the model to a computer representation. Example artifacts produced during model conceptualization include: system description, diagrams, rich pictures, context diagrams, activity diagrams, flow charts, information diagrams (e.g. UML), and pseudo-code

**1.8** The act of implementing the model in computer code, including timing and general procedures and the representation of the conceptual model into a computer simulation program is called: .

Model translation

**1.9** Which of the following does the problem formulation phase of simulation not include?

a) Define the system

 b) Establish performance metrics

c) Verification

d) Build conceptual models

See page 9 of text**:** c) Verification

**1.10** The general goals of a simulation study often include:

(a). \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  of system alternatives and their performance measures across various factors (decision variables) with respect to some objectives.

(b). \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of system behavior at some future point in time.

See page 11:

a) To compare

b) To predict

**1.11** *True* or *False* Verification of the simulation model is performed to determine whether the simulation model adequately represents the real system.

False. The statement describes validation, not verification.

**Chapter 2 Solutions for Simulation Modeling and Arena, 2nd Edition, by Manuel D. Rossetti, John-Wiley & Sons.**

**Exercises**

**2.1** The sequence of random numbers generated from a given seed is called a random number (a) .

(a) Stream

**2.2** State three major methods of generating random variables from any distribution.

(a) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (b) \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ (c)\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(a) inverse transform, (b) convolution, (c) acceptance/rejection

**2.3** Consider the multiplicative congruential generator with (a = 13, m = 64, and seeds X0 = 1,2,3,4)

a) Does this generator achieve its maximum period for these parameters? Use Theorem 2.1 to justify your answer.

b) Generate a period’s worth of uniform random variables from each of the supplied seeds.

*a* = 13, *m* = 64, and *X0* = 1, 2, 3, 4

1. The multiplicative linear congruential generator is a special case of the linear congruential generator, therefore the LCG theorem can be applied to check if the generator will achieve its maximum period. The theorem states that an LCG has a full period if and only if the following three conditions hold:
2. The only positive integer that (exactly) divides both *m* and *c* is 1 (i.e. *c* and *m* have no common factors other than 1).
3. If *q* is a prime number that divides *m* then *q* should divide (*a*-1) (i.e. (*a*-1) is a multiple of every prime number that divides *m*).
4. If 4 divides *m*, then 4 should divide (*a*-1) (i.e. (*a*-1) is a multiple of 4 if *m* is a multiple of 4).

* Condition 1 does not hold because *c* = 0, meaning that *m* and *c* have multiple common factors.
* Condition 2 holds because the prime numbers, *q*, that divide *m* = 64 are 1 and 2. (*a*-1) = 12, and both 1 and 2 divide 12.
* Condition 3 holds because 4 divides both *m* = 64 and (*a*-1) = 12.

Also, since *m* is a power of 2 (*m* = 64 = 26) and *c* = 0, the longest possible period is *m*/4 = 64/4 = 16.

1. Below is a period’s worth of uniform random variables from each of the supplied seeds.

For Xo = 1,

Table 4 – A Period’s Worth of Uniform Random Variables



For Xo = 2,

Table 5 – A Period’s Worth of Uniform Random Variables



For Xo = 3,

Table 6 – A Period’s Worth of Uniform Random Variables



For Xo = 4,

Table 7 – A Period’s Worth of Uniform Random Variables



**2.4** Consider the multiplicative congruential generator with (a = 11, m = 64, and seeds X0 = 1,2,3,4)

a) Does this generator achieve its maximum period for these parameters? Use Theorem 2.1 to justify your answer.

b) Generate a period’s worth of uniform random variables from each of the supplied seeds.

Condition 1 does not hold because *c* = 0, meaning that *m* and *c* have multiple common factors. Thus, it cannot reach its full period. Also, since *m* is a power of 2 (*m* = 64 = 26) and *c* = 0, the longest possible period is *m*/4 = 64/4 = 16.