CS-417
COMPUTER SYSTEMS MODELING

Spring Semester 2020

Batch: 2016-17

(LECTURE # 25)

FAKHRA AFTAB

LECTURER

DEPARTMENT OF COMPUTER & INFORMATION SYSTEMS ENGINEERING

NED UNIVERSITY OF ENGINEERING & TECHNOLOGY

Recap of Lecture # 24

Open and Close Queuing Networks

Jackson’s and Burke’s Theorem

Two Stages Tandem Network

Open Central Server Network

Chapter # 7

SIMULATION MODELING

Simulation

The technique of using a computer to imitate the operation of an entire process or system

- **Purpose:** provides a way to predict the performance of a computer system or compare several alternatives.
- **When to use simulation:** the stochastic system involved is too complex to be analyzed satisfactorily by the kinds of mathematical models (e.g., queuing models).

Advantages

- Simulation is much *less expensive* than actually building a machine.
- It is much *more flexible* than measuring the performance of a real machine.
- Simulation allows a system to be studied in *more detail* than analytical modeling.
- Simulation enables to *study dynamic systems* in real, compressed or expanded time.

Terminology

- **State Variables:** The variables whose values define the state of the system. In the CPU scheduling simulation, the state variable is the *length of the job queue*.

- **Event:** A change in the system state. In the CPU scheduling simulation, there are two events: *arrival of a job* and *departure of a job*.

- **Continuous-Time and Discrete-Time Models**
  - CT models: A model in which the system state is defined at all times. e.g. the CPU scheduling model.
  - DT models: The system state is defined only at particular instants in time. e.g. a process that activates every 5-msec and records the number of blocked processes in the system.

- **Continuous-State and Discrete-State Models:**
  - CS models: State variables are continuous e.g. pressure of gas in thermodynamic systems. Also called a continuous-event model.
  - DS models: state variables are discrete e.g. length of job queue. Also called a discrete-event model.

Thus, there are four possible combinations:

- discrete state/discrete time,
- discrete state/continuous time,
- continuous state/discrete time, and
- continuous state/continuous time models.

- **Open and Closed Models**

  - Open model: The input is external to the model and is independent of it. e.g. new jobs enter the model from outside.

  - Closed model: There is no external input. e.g. the same jobs keep circulating in the model. A job departing the second queue reenters the first queue. This is therefore a closed model.

Simulation Efficiency Considerations

1) An important limitation of simulation: the simplifying assumptions restrict its ability to exactly duplicate the behavior of a real system.

2) Determining the level of detail necessary when writing a new simulator depends on the level of detail necessary to solve the problem, and the consequences of being wrong.

- E.g., the consequences of being wrong when using a simulator to determine the best cache size for a new system are relatively small.
- The incorrect operation of a microprocessor used to control a heart pacemaker, though, can have much more serious consequences. Thus, in this case, a very detailed simulation may be warranted.

Types of Simulations

- Emulation
- Static (or Monte-Carlo) simulation
- Discrete-event simulation
- Continuous-event simulation

1) Emulation

- An **emulator** is hardware or software that enables one computer system (called the *host*) to behave like another computer system (called the *guest*). An emulator typically enables the host system to run software or use peripheral devices designed for the guest system.

- Emulation allows program to run on the platform other than the one for which they were originally developed.

- For Example
  - Android Emulator
  - DOSBox emulates the command-line interface of DOS

2) **Static (Monte Carlo) Simulation**

- No time parameter.

- The simulation is run until further refinement of the state of the simulated system is no longer useful or possible.

- Static simulations are often used to evaluate some physical phenomenon (probabilistically), or to numerically estimate the solution of some mathematical expression, such as a complex integral.

Example

- Consider the problem of numerically determining the value of π.
- We begin with a geometric description as shown in Figure 1.
- Since the area of a circle with a radius of 1 is $\pi(1)^2 = \pi$, the area of the quarter-circle within the first quadrant is $\pi/4$.
- The area contained within the unit square in this quadrant is simply 1.
- Thus, the ratio of the area of the quarter-circle to the area of the square, which we denote R, is $R=\pi/4$.

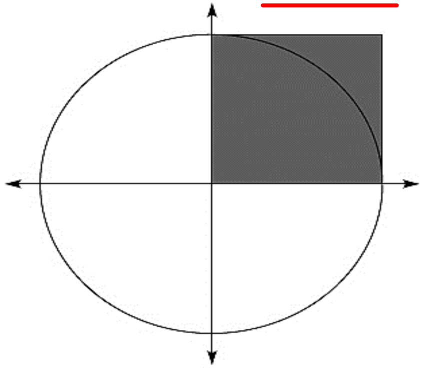

Figure 1: A simple Monte Carlo simulation, to estimate the numerical value of π.

- The numerical value of π then can be found from π=4R.
- The problem of computing the value of π has been transformed into the equivalent geometric problem of determining the ratio of the two areas, R.
- A Monte Carlo simulation can be used to find R by modeling an equivalent physical system.
- Imagine throwing a large number of darts randomly at figure 1 such that every dart hits within the unit square.
- Then we count the number of times a dart hit within the quarter-circle, n_{circ}, and the total number of darts thrown, n_{total}.
- Then the desired ratio of the two areas is $R = n_{circ}/ n_{total}$.

- We can simulate this dart-throwing experiment by generating two random numbers, u_1 and u_2, for each dart thrown, such that u_1 and u_2 are both uniformly distributed between 0 and 1.

$\pi = 4R$

- If the distance from the origin of the point defined by $(x,y) = (u_1,u_2)$ is smaller than the radius of the circle, that is, $u_1^2 + u_2^2 \leq 1$, then the simulated dart has hit within the quarter-circle.

- By repeating this process a large number of times, we can theoretically compute the value of π to any level of precision desired.

- The key to this type of Monte Carlo simulation is identifying an appropriate physical model for the system being studied.

Example Problem

Monte Carlo Simulation can be used in several application areas including forecasting models, financial & cost analysis, project management etc .

Choose any application area & provide a detailed example of Monte Carlo Simulation.