Discrete-Event Simulations

Review of Systems

A **system** is a group of entities that coexist and interact, usually towards the accomplishment of some goal. Systems are embedded within a larger environment, called the **system environment**. There is typically an exchange of information and resources between the system and its enviroment. Note however that the distinction between a system and its environment represents more of a logical division for the sake of model development. In most cases, a system represents an integrated part of its environment; not a separate entity.

A **system simulation** is the process of imitating the operation of a system over time.

Elements of a System Model

Entities refer to the relevant things within a system.

Rules govern how entities interact with one another. Rules help determine what will happen next in the system as the result of some system event.

Inputs represent data that is needed to populate various attributes of system entities.

Activities represent things happening in the system over a period of time.

Delays represent future activities that will begin and end in some possibly unknown time in the future. Delays are the result of not having enough resources at a given time to allow for all desired activities to take place.

System State represents a collection of variables that is sufficient for describing the system at any given time. These variables are usually defined as a subset of the collective set of individual entity attributes.

Events are instantaneous occurrences that changes the state of the system. Two types of events include

1. **internal:** events occurring within the system.

2. **external:** events occurring outside the system, or in the system environment. These events usually represent the addition (subtraction) of an entity to (from) the system.

A system is said to be **discrete** if the system state changes at discrete moments in time. When this is the case, the system lends itself to being simulated by a **discrete-event simulation (DES)**, which is a process that imitates the discrete changes of a system's state over time, which in turn is accomplished by imitating the entire chronological sequence of events that occur within a system over time. This is true since, by definition, a system changes state as the result of the occurence of some system event. Thus, to perform a discrete-event system simulation, one most know the different kinds of events that may occur in a system. Moreover, for each specific event E, one must have knowledge of the

1. time at which E occurred,
2. system entities/variables that are affected/changed by E, and
3. future events that are caused by E.

Hence, a discrete event simulation has the task of processing each event and updating the system state variables accordingly.

The Event Scheduling Time Advance (ESTA) Algorithm

1. Initialize all system entities, including the system clock
2. Intialize the future-event list (FEL) with one or more future-event notices
3. While the FEL is nonempty,
   (a) Remove the minimum event-notice E from the FEL heap
   (b) Advance the system clock C so that $C = E.\text{time}$
   (c) Process E and update the system state. Such updates may include (but are not limited to)
      i. updating the state of all entities to which E pertains
      ii. making a server available/busy
      iii. removing/adding customers to queues
      iv. cancelling a future event
   (d) Generate any future events that were caused by E and insert them into the FEL

Example 1. The following table shows both the arrival (in minutes after the hour) and service times for customers at an ATM machine. Use the ESTA algorithm to run a simulation with the data below.

Customer	**Arrival time (min. after hr.)**	**Service time (min.)**	**Departure time (min. after hr.)**
Al	0	5	
Bo	3	7	
Cat	4	1	
Du	7	3	
Ed	9	2	

Example 2. A full adder circuit is designed using AND, OR, and EXOR gates. The AND and OR gates have a delay of 2.4 ns, while the EXOR gate has a delay of 4.2 ns. Assume all wires have a 1.0 ns delay. Assume that at time zero the inputs a and b are assigned the boolean values 0 and 1 respectively at time 0, while c_in is assigned the value of 1 at time 0. Show how these signals propagate through the circuit by using the ESTA algorithm. Show the sequence of state changes that occur during the simulation.