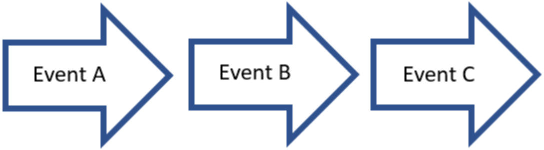
Discrete Event Simulations



Outline

Learning Objectives

By the end of this video, we hope that you will be able to:

- Understand the elements and variables needed to create a discrete event simulation
- Understand how to design and plan your own discrete event simulation.

Designing a Discrete Event Model

Discrete Event Model

In DES models, observations are gathered at selected (discrete) points in time, when certain changes take place in the system. These selected time points are known as **events**.

Events that are not appropriate for DES model

- Consider a simulation of disease spreading through a population. People are continually (in time) getting infected, infecting others and recovering. Of course, we could set fixed periods of say, months, and then simulate the transitions as a block, but it is easier to model the rate of transitions.
- Now consider simulating traffic on a network of roads. As events such as traffic signals, accidents, acceleration and deceleration are continually changing the composition of the system, it is not appropriate to introduce arbitrary time-checkpoints and only record the system values at those points.

Discrete Event Model

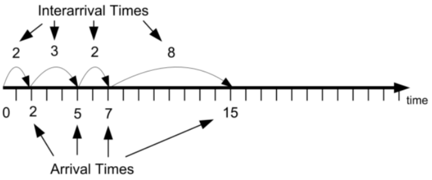


Figure 2.14: Customer arrival process

Table 2.2: Customer time of arrivals

Customer	Time of arrival	Time between arrival
1	2	2
2	5	3
3	7	2
4	15	8

- Now consider ABC bank - it has 2 tellers who serve customers from a single waiting line.
- The bank opens at 9am, at which point customers begin to arrive.
- When a customer arrives, he goes to any one of the tellers that is available.
- If both are occupied, he has to join a queue.

Discrete Event Model

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In a discrete-event simulation the clock does not "tick" at regular intervals. Instead, the simulation clock jumps from event time to event time.

- As the simulation moves from the current event to the next event, the current simulation time is updated to the time of the next event and any changes to the system associated with the next event are executed.
- This allows the simulation to evolve over time.

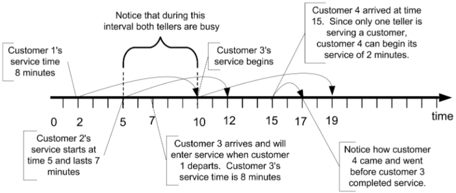

Figure 2.15: Customer service process

Table 2.3: Service time for first four customers

Customer	Service Time Started	Service Time	Service Time Completed
1	2	8	10
2	5	7	12
3	10	9	19
4	15	2	17

Discrete Event Model

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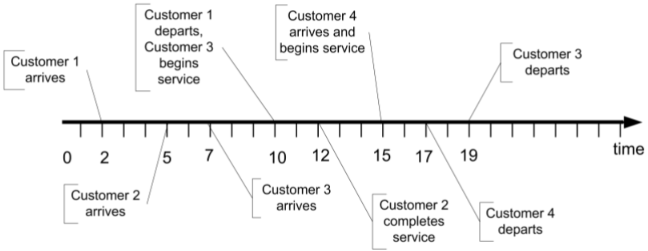
In order to mimic the daily operation of ABC bank on a computer, we would need to perform very careful bookkeeping.

Most DES software adopt an alternative - a "process" view of the system.

In a process-oriented view, we only consider the sequence of activities that occur, where an activity is just something that takes an interval of time to complete.



Elements of DES models

In order to proceed, we need to understand some terms and concepts used when developing a simulation model.

- **System** is A set of inter-related components that act together over time to achieve common objectives.
- **Parameters** are typically quantities (variables) that are part of the environment, that the modeler feels cannot be controlled or changed.
- **Variables** are quantities that are properties of the system (as a whole) that change or are determined by the relationships between the components of the system as it evolves through time.
- **System State** is a ”snap shot” of the system at a particular point in time, characterized by the values of the variables that are necessary for determining the future evolution of the system.
- **Entity** is an object of interest in the system whose movement or operation within the system may cause the occurrence of events.

Elements of DES models

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- **Attribute** is a named property or variable that is associated with an entity type. In the bank case, by the time an entity exits the system.
- **Event** is an instantaneous occurrence or action that changes the state of the system at a particular point in time. The following are the only two events in the bank case: the arrival of a customer and the departure of a customer.
- **Activity** is an interval of time bounded by two events (start event and end event).
- **Resource** is a limited quantity of items that are first seized, and then released by entities as they proceed through the system.
- **Queue** is a location that holds entities when their movement is constrained within the system.
- **Future Event List** is a list that contains the time ordered sequence of events for the simulation.

Prior to coding up a model, it is imperative to identify the elements of the system that corresponds to the elements listed above.

Entities and Attributes

Modelling a DES from the process-view requires us to think carefully about the journey that the entities undergo. In the R package that we shall introduce next week, this is referred to as the "trajectory" of the entity.

Let us looks at a supermarket scenario. Besides the customers, what are other entities that you might want to take into account?

- What about the products that are sitting on shelves, waiting for a customer to purchase them? These can also be considered as entities.
- Entities can be considered as a group or as individuals too. (E.g. products placed together in a tote bag can be considered as an entity.
- The individual items can be distinguished by their attributes. Attributes can be thought of as variables that are attached to the entity.
- The system itself could have some external attributes. (E.g. the number of customers, the number of supermarket baskets and the number of cashier counters.)

Variable Types

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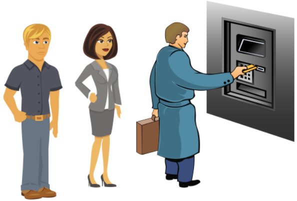
The value of a DES model is in the measures of performance that we can extract from it. There are two kinds of variables that we focus on: time persistent statistics, and tally statistics.

- In the ABC bank example, an example of a tally statistic is the average waiting time of individual customers.
- Another example of tally statistic is the average service time of customers.



In contrast

Consider the number of people in the queue between 9am and 5pm. This is clearly a function of time.

- In deriving a single number to represent the queue length over the course of the day, we have to do a time-average.

Summary

Learning Outcomes

- As you can see from the cursory treatment of the two scenarios above, we have many options: from what entities to represent, right up to what statistics to compute from the simulation output.
- we have to re-run our simulation many times, and take averages, because we cannot rely on a single simulation run alone. This begs the question, "How many simulation runs do we need?".

References

Rossetti, M. (2015). *Simulation Modelling and Arena.* John Wiley Sons.