Simulation and Modelling

NATIONAL UNIVERSITY of Computer & Emerging Sciences

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CS4056

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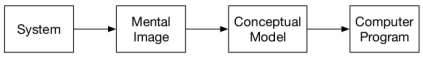
Notes

Building Conceptual Models

Notes

WHAT IS A CONCEPTUAL MODEL?

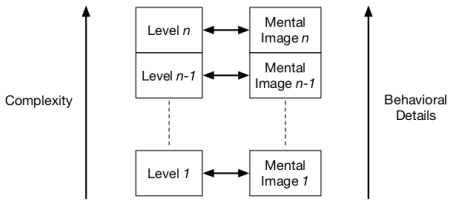
- A conceptual model is a representation of a system using specialized concepts and terms.
- a mathematical model of a system can be thought of as a conceptual model that is constructed using specialized concepts such as constants, variables, and functions and specialized terms such as derivative and integral.
- before a conceptual model can be built, a mental image of the system under study must be developed in the mind of the modeler
- A mental image reflects how the modeler perceives the system and its operation.
- The mental image should include only those aspects of the system that are necessary for the simulation study.



Notes

Mental image

- Different mental images can be developed for the same system. They include different levels of details. Complexity increases as more details are added.



Notes

ELEMENTS OF A CONCEPTUAL MODEL

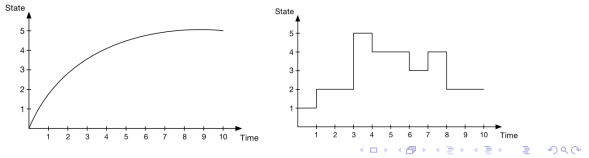
A conceptual model can be constructed using five elements:

- Entity:
  - An entity represents a physical (or logical) object in the system.
  - The server is a static entity because it does not move in the system and its purpose is to provide service only for other entities.
  - A person is a dynamic entity because it moves through the system.
  - A static entity maintains a state that can change during the lifetime of the system.
  - On the other hand, dynamic entities do not maintain any state.
- Attribute:
  - A dynamic entity typically has attributes which are used for storing data.
  - An entity is characterized using attributes, which are local variables defined inside the entity.
  - a person can have an attribute for storing the time of his arrival into the system (i.e., arrival time).

Notes

ELEMENTS OF A CONCEPTUAL MODEL

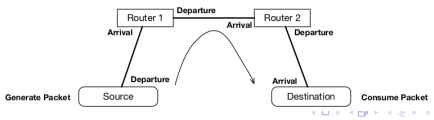
- State Variable:
  - A state variable is used to track a property of a static entity over time.
  - for a memory module in a system, its state could be the number of data units it currently stores.
  - state of a cashier in the supermarket example. It is either free or busy.
  - A state variable is said to be continuous if it takes values that change continuously over time.
  - if the value of a state variable is from a discrete set, then it is referred to as a discrete state variable.



Notes

ELEMENTS OF A CONCEPTUAL MODEL

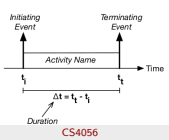
- Event
  - An event represents the occurrence of something interesting inside the system.
  - It is a stimulus that causes the system to change its state.
  - In the supermarket example, the arrival of a new customer represents an event which will cause the state variable representing the number of people waiting in line to increase by one.
  - The departure of a customer will cause the cashier to become free.
  - Events can be used to delimit activities and move active entities
  - a packet is moved from a source to a destination using eight events.



Notes

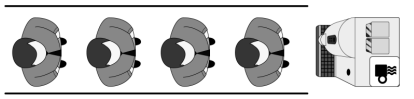
ELEMENTS OF A CONCEPTUAL MODEL

- Activity.
  - An activity is an action which is performed by the system for a finite (but random) duration of time.
  - The initiating event starts the activity.
  - The end of the activity is scheduled at the time of occurrence of the terminating event.
  - The difference in time between the two events represents the duration of the activity.
  - Durations of activities are modeled as random variables.
  - An important activity is the time a customer spends at the checkout.The duration of this activity depends on how many items the customer has.



Notes

SINGLE-SERVER QUEUEING SYSTEM

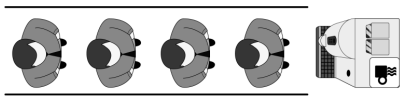


- Consider the situation depicted in Figure where there is one coffee machine and multiple users. Only one user can use the machine at a time. Thus, the others have to wait
- Mental Image
- conceptual model

Element
Entity
State Variables
Events
Activities

Notes

SINGLE-SERVER QUEUEING SYSTEM

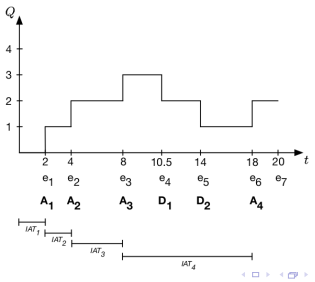


Element	Details
Entity	Queue, Server, Person
State Variables	Q = Number of Persons in Queue Q ∈ {0, 1, 2, ...} S = Status of Server S ∈ {Free, Busy}
Events	Arrival, Start_Service, End_Service (or Departure)
Activities	Generation, Waiting, Service, Delay

Notes

SINGLE-SERVER QUEUEING SYSTEM

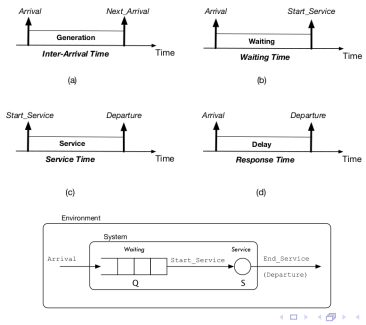
Sample paths of DESs have a special shape which can be represented by a piecewise constant function.
The time between two such arrivals is random and it is referred to as the Inter-Arrival Time (IAT).



Notes

SINGLE-SERVER QUEUEING SYSTEM

Four possible activities take place inside the single-server queueing system.



Notes

Simulating a Single-Server Queue

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A small grocery store has one checkout counter. Customers arrive at the checkout counter at random times that range from 1 to 8 minutes apart. We assume that interarrival times are integer-valued with each of the 8 values having equal probability; this is a discrete uniform distribution. The service times vary from 1 to 6 minutes (also integer-valued), with the probabilities shown in Table below. Our objective is to analyze the system by simulating the arrival and service of first 10 customers and to compute a variety of typical measures of performance for queueing models.

Service Times (Minutes)	Probability	Cumulative Probability
1	0.10	0.10
2	0.20	0.30
3	0.30	0.60
4	0.25	0.85
5	0.10	0.95
6	0.05	1.00

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Inter arrival Times (minutes)	
Minimum	1
Maximum	8

Simulation Table

Step	Activity	Clock	Activity	Clock	Output	Clock	Output	Output
Customer	Interarrival Time (Minutes)	Arrival Time	Service Time (Minutes)	Time Service Begins	Waiting Time in Queue (Minutes)	Time Service Ends	Time Customer Spends in System (Minutes)	Idle Time of Server (Minutes)
1	3	3	3					
2	2	5	2					
3	8		3					
4	6		5					
5	2		4					
6	1		1					
7	7		2					
8	6		4					
9	7		6					
10	6		2					

Notes

Simulating a Single-Server Queue

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- The average waiting time for a customer is _____ minutes, computed as follows:

$$\text{Average waiting time(minutes)} = \frac{\text{total time customers wait in queue (minutes)}}{\text{total numbers of customers}}$$

- The probability that a customer has to wait in the queue is _____, computed as follows:

$$\text{Probability (wait)} = \frac{\text{numbers of customers who wait}}{\text{total number of customers}}$$

- The server is idle about _____% of the time, computed as follows:

$$\text{Probability of idle} = \frac{\text{total idle time of server (minutes)}}{\text{total run time of simulation (minutes)}}$$

Therefore, the server is busy about _____% of the time.

- The average service time is _____ minutes, computed as follows:

$$\text{Average service time(minutes)} = \frac{\text{total service time (minutes)}}{\text{total number of customers}}$$

- Comparing average service time with the expected service time by finding the mean of the service-time distribution

$$E(S) = \sum_{s=0}^{\infty} s \times P(s)$$

Notes

Simulating a Single-Server Queue

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- The average time between arrivals is _____ minutes, computed as follows:

$$\text{Average time between arrivals} = \frac{\text{sum of all times between arrivals}}{\text{number of arrivals-1}}$$

- Compared to the expected time between arrivals by finding the mean of the discrete uniform distribution whose endpoints are $a = 1$ and $b = 8$. The mean is given by

$$E(A) = \frac{a+b}{2} =$$

- The average waiting time of those who wait is _____ minutes, computed as follows:

$$\text{Average waiting time of those who wait} = \frac{\text{total time customers wait in queue}}{\text{total number of customers who wait}}$$

- The average time a customer spends in the system is _____ minutes, computed in ways.

$$\text{Average time customer spends in the system} = \frac{\text{total time customers spend in the system}}{\text{total number of customers}}$$

Average time customer spends in the system (minutes) = average time customer spends waiting in the queue (minutes) + average time customer spends in service (minutes)

Notes