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Internal Assessment Test 3 – July. 2021

Sub:	**SYSTEM MODELING AND SIMULATION**			Sub Code:	**17CS834**	Branch:	**ISE**
Date:	17-07-21	Duration:	90 min’s	Max Marks:	50	Sem / Sec:	VIII/ A ,B (ISE)

OBE

Answer any FIVE FULL Questions — MARKS — CO — RBT

1 List and explain the characteristics of queuing system. Briefly explain queuing notations**.** [10] CO3 L2

2 Let the arrival distribution be uniformly distributed between 1 to 8 min. Develop a simulation table for 10 customers. The service time distributions are as follows. [10] CO1 L3

Service Time	1	2	3	4	5	6
Probability	0.05	0.10	0.20	0.30	0.25	0.10

Consider the following random numbers for inter Arrival Times and Service Times.
Random No for IAT: 913, 727, 153, 948 ,309 ,929 ,756 ,234 ,697
Random No for Service Times: 84, 10, 74, 53, 17, 79, 91, 67, 89, 38.
Find the average waiting time, average service time and average time customer spends in system.

3. Describe the three steps approach to validate by Naylor & Finger in the validation process. [10] CO3 L1

4. Consider the following inter arrival times and service times. Using time advance algorithm prepare a simulation table based on the following activities and stop the Simulation when clock reaches 20**.** [10] CO2 L3

Inter arrival Time	3	2	6	2	4	5
Service Time	2	5	5	8	4	5

5. Discuss with the help of neat diagram model building, verification & validation. [10] CO3 L1

6. Explain output analysis for steady state simulation in detail. [10] CO3 L1

Scheme of Evaluation

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Note: Answer Any Five Questions

Question #	**Description**	**Marks Distribution**	**Max Marks**
1	Characteristics of Queuing System: • The Calling Population explanation • System Capacity • Arrival process • Queue behaviour and Queue Discipline • Service Time and Service Mechanism Queuing Notations	8M (2+1+1+2+2) 2M	10 M
2	• For finding the cumulative probability and random numbers for IAT • For finding the cumulative probability and random numbers for service times • For finding the Inter-arrival times and arrival times • For finding the service times from the random numbers • For finding the time service begins, time service ends, waiting time etc. • For finding the average waiting time and Probability of idle time of server	1 M 1 M 1 M 1M 5M 1M	10 M
3	Defining 3step approach Explanation of all the three steps 1. Build a model that has high face validity. 2. Validate model assumptions. 3. Compare the model input-output transformations to corresponding input-output transformations for the real system.	1M 3*3 =9M	10 M
4	• For defining the system states like LQ(t),LS(t) • -For defining the Future Event List • -For Updating the Cumulative statistics like B and MQ • -For Simulation table defining all the above entities	2 M 4 M 2 M 2 M	10 M
5	• Diagram • Explanation	4M 6M	10 M
6	Explaining steady state simulation • Initialization bias • Error estimation • Replication Method	1M 3*3 =9M	10 M

Internal Assessment Test 3 Solutions– July.2021

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Note: Answer Any Five Questions

1. List and explain the characteristics of queuing system. Briefly explain queuing notations**.**

Solution:

Key elements of queueing systems:

- Customer: refers to anything that arrives at a facility and requires service, e.g., people, machines, trucks, emails.
- Server: refers to any resource that provides the requested service, e.g., repairpersons, retrieval machines, runways at airport.

Characteristics of queuing system:

- Calling population
- System Capacity
- Arrival Process
- Queue behavior and Queue Discipline
- Service Times and Service Mechanism

- **Calling population**: the population of potential customers, may be assumed to be finite or infinite.
  - Finite population model: if arrival rate depends on the number of customers being served and waiting, e.g., model of one corporate jet, if it is being repaired, the repair arrival rate becomes zero.
  - Infinite population model: if arrival rate is not affected by the number of customers being served and waiting, e.g., systems with large population of potential customers.
- **System Capacity**: a limit on the number of customers that may be in the waiting line or system.
  - Limited capacity, e.g., an automatic car wash only has room for *10* cars to wait in line to enter the mechanism.
  - Unlimited capacity, e.g., concert ticket sales with no limit on the number of people allowed to wait to purchase tickets.
- **Arrival Process:**

  For infinite-population models:
  - Random arrivals: interarrival times usually characterized by a probability distribution.
    - Most important model: Poisson arrival process (with rate λ), where A_n represents the interarrival time between customer $n-1$ and customer n, and is exponentially distributed (with mean $1/\lambda$).
  - Scheduled arrivals: interarrival times can be constant or constant plus or minus a small random amount to represent early or late arrivals.
    - e.g., patients to a physician or scheduled airline flight arrivals to an airport.
  - At least one customer is assumed to always be present, so the server is never idle, e.g., sufficient raw material for a machine.
- For finite-population models:
  - Customer is pending when the customer is outside the queueing system, e.g., machine-repair problem: a machine is “pending” when it is operating, it becomes “not pending” the instant it demands service form the repairman.

  - Runtime of a customer is the length of time from departure from the queueing system until that customer’s next arrival to the queue, e.g., machine-repair problem, machines are customers and a runtime is time to failure.
- **Queue behavior:** the actions of customers while in a queue waiting for service to begin, for example:
  - Balk: leave when they see that the line is too long,
  - Renege: leave after being in the line when its moving too slowly,
  - Jockey: move from one line to a shorter line.
- **Queue discipline**: the logical ordering of customers in a queue that determines which customer is chosen for service when a server becomes free, for example:
  - First-in-first-out (FIFO)
  - Last-in-first-out (LIFO)
  - Service in random order (SIRO)
  - Shortest processing time first (SPT)
  - Service according to priority (PR).
- **Service Times and Service Mechanism:**

  Service times of successive arrivals are denoted by S_1, S_2, *and S3*.
  - May be constant or random.
  - $\{S_1, S_2, S_3, \ldots\}$ is usually characterized as a sequence of independent and identically distributed random variables, e.g., exponential, Weibull, gamma, lognormal, and truncated normal distribution.
- A queueing system consists of a number of service centers and interconnected queues.
  - Each service center consists of some number of servers, *c*, and working in parallel, upon getting to the head of the line, a customer takes the 1^{st} available server.

Queuing Notation: A notation system for parallel server queues: *A/B/c/N/K*

- *A* represents the interarrival-time distribution,
- *B* represents the service-time distribution,
- *c* represents the number of parallel servers,
- *N* represents the system capacity,
- *K* represents the size of the calling population.

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2. Solution:

Inter arrival time ranges from 1 to 8 min with equal probability.

So probability = 1/8 =0.125

IAT	Probability	Cumulative Probability	Random No Assessment
1	0.125	0.125	1-125
2	0.125	0.250	126-250
3	0.125	0.375	251-375
4	0.125	0.500	376-500
5	0.125	0.625	501-625
6	0.125	0.750	626-750
7	0.125	0.875	751-875
8	0.125	1.000	876-1000
ST	Probability	Cumulative Probability	Random No Assessment
1	0.10	0.10	1-10
2	0.20	0.30	11-30
3	0.30	0.60	31-60

4	0.25	0.85	61-85
5	0.10	0.95	86-95
6	0.05	1.00	96-100

Main Simulation table:

Customer	IAT	AT	ST	Time Service Begins	Waiting Time	Time Service Ends	Time customer Spend in system	Idle time of server
1	-	0	2	0	0	2	2	0
2	5	5	2	5	0	7	2	3
3	5	10	4	10	0	14	4	3
4	4	14	4	14	0	18	4	0
5	2	16	3	18	2	21	5	0
6	8	24	2	24	0	26	2	3
7	7	31	3	31	0	34	3	5
8	8	39	5	39	0	44	5	5
9	5	44	1	44	0	45	1	0
10	2	46	6	46	0	52	6	1
	Total		32		2		34	20

Average WT = Total WT/Total No of customers =7/10
Average ST = Total ST/Total no of customers = 32/10
Avg time customer spends in system = Total time spend in system/ Total no of customers = 34/10

3. Describe the three steps approach to validate by Naylor & Finger in the validation process.

Solution

Naylor and Finger formulated a **three step approach** which has been widely followed:-

1. Build a model that has high face validity.
2. Validate model assumptions.
3. Compare the model input-output transformations to corresponding input-output transformations for the real system.

1. Face Validity

- The first goal of the simulation modeler is to construct a model that appears reasonable on its face to model users and others who are knowledgeable about the real system being simulated.

- The users of a model should be involved in model construction from its conceptualization to its implementation to ensure that a high degree of realism is built into the model through reasonable assumptions regarding system structure, and reliable data.

- Another advantage of user involvement is the increase in the models perceived validity or credibility without which manager will not be willing to trust simulation results as the basis for decision making.

- Sensitivity analysis can also be used to check model's face validity.

- The model user is asked if the model behaves in the expected way when one or more input variables is changed.

- Based on experience and observations on the real system the model user and model builder would probably have some notion at least of the direction of change in model output when an input variable is increased or decreased.

• The model builder must attempt to choose the most critical input variables for testing if it is too expensive or time consuming to: vary all input variables.

2. Validation of Model Assumptions

• Model assumptions fall into two general classes: structural assumptions and data assumptions.

Structural assumptions involve questions of how the system operates and usually involve simplification and abstractions of reality.

• For example, consider the customer queuing and service facility in a bank. Customers may form one line, or there may be an individual line for each teller. If there are many lines, customers may be served strictly on a first-come, first-served basis, or some customers may change lines if one is moving faster. The number of tellers may be fixed or variable. These structural assumptions should be verified by actual observation during appropriate time periods together with discussions with managers and tellers regarding bank policies and actual implementation of these policies.

• Data assumptions should be based on the collection of reliable data and correct statistical analysis of the data.

3. Validating Input-Output Transformation

In this phase of validation process the model is viewed as input –output transformation: That is, the model accepts the values of input parameters and transforms these inputs into output measure of performance. It is this correspondence that is being validated.

- **Using historical input data** : Instead of validating the model input-output transformation by predicting the future, the modeler may use past historical data which has been served for validation purposes that is, if one set has been used to develop calibrate the model, its recommended that a separate data test be used as final validation test.
- **Using Turing test**: When no statistical test is readily applicable then persons knowledgeable about system behavior can be used to compare model output with system output. This type of test is called Turing test used in detecting model inadequacies and to increase the model credibility.

4. Solution:

Clock	System State		Future Event List	Comments	Cumulative Statistics	
	LQ(t)	LS(t)			B	MQ
0	0	1	(D,2)(A,3)(E,20)	1st Customer arrived	0	0
2	0	0	(A,3)(E,20)	1st Customer departured	2	0
3	0	1	(A,5)(D,8)(E,20)	2nd Customer arrived	2	0
5	1	1	(D,8)(A,11)(E,20)	3rd Customer Arrived	4	1
8	0	1	(A,11)(D,13)(E,20)	2nd Customer Departured	7	1
11	1	1	(A,13)(D,13)(E,20)	4th Customer Arrived	10	1
13	1	1	(A,17)(D,21)(E,20)	5th Customer Arrived & 3rd Customer Departured	12	1
17	2	1	(A,21)(D,21)(E,20)	6th Customer Arrived	16	2
20	2	1	(A,21)(D,21)	End of simulation time	19	2

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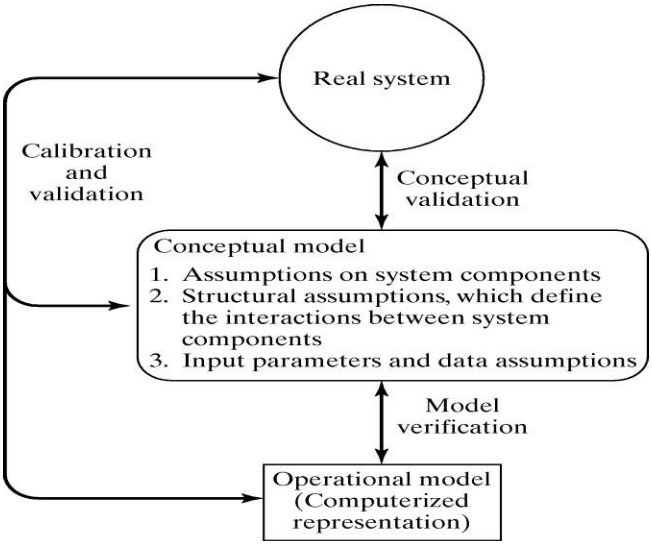
5. Explain the components of verification and validation process. Explain with neat diagram model building, verification and validation process.



The first step in model building consists of observing the real system and the interactions among its various components and collecting data on its behavior.

• Operators, technicians, repair and maintenance personnel, engineers, supervisors, and managers under certain aspects of the system which may be unfamiliar to others.

• As model development proceeds, new questions may arise, and the model developers will return, to this step of learning true system structure and behavior.

• The second step in model building is the construction of a conceptual model – a collection of assumptions on the components and the structure of the system, plus hypotheses on the values of model input parameters, illustrated by the following figure.

• The third step is the translation of the operational model into a computer recognizable form- the computerized model.

6. Solution:

- Consider a single run of a simulation model to estimate a steady-state or long-run characteristics of the system.
    - The single run produces observations $Y_1, Y_2, \ldots$ (generally the samples of an auto correlated time series).
    - Performance measure:

$$\theta = \lim_{n\to\infty} \frac{1}{n} \sum_{i=1}^{n} Y_i, \qquad \text{for discrete measure}$$

$$\phi = \lim_{T_E\to\infty} \frac{1}{T_E} \int_0^{T_E} Y(t)dt, \qquad \text{for continuous measure}$$

- **Initialization Bias**: Methods to reduce the point-estimator bias caused by using artificial and unrealistic initial conditions:
    - Intelligent initialization.
    - Divide simulation into an initialization phase and data-collection phase.
- **Intelligent initialization**
    - Initialize the simulation in a state that is more representative of long-run conditions.
    - If the system exists, collect data on it and use these data to specify more nearly typical initial conditions.
    - If the system can be simplified enough to make it mathematically solvable, e.g. queueing models, solve the simplified model to find long-run expected or most likely conditions, use that to initialize the simulation.
- Divide each simulation into two phases:
    - An initialization phase, from time 0 to time T_0.
    - A data-collection phase, from T_0 to the stopping time T_0+T_E.
    - The choice of T_0 is important:
        - After T_0, system should be more nearly representative of steady-state behavior.
    - System has reached steady state: the probability distribution of the system state is close to the steady-state probability distribution (bias of response variable is negligible).

- **Error Estimation:**

If $\{Y_1, \ldots, Y_n\}$ are not statistically independent, then S^2/n is a biased estimator of the true variance.

- Almost always the case when $\{Y_1 \ldots Y_n\}$ is a sequence of output observations from within a single replication (auto correlated sequence, time-series).

Suppose the point estimator θ is the sample mean

$$\bar{Y} = \sum_{i=1}^{n} Y_i \,/\, n$$

- Variance of is almost impossible to estimate.
    - For system with steady state, produce an output process that is approximately covariance stationary (after passing the transient phase).

  - The covariance between two random variables in the time series depends only on the lag (the # of observations between them).

- **Replication Method:**
  - Use to estimate point-estimator variability and to construct a confidence interval.
  - Approach: make R replications, initializing and deleting from each one the same way.
  - Important to do a thorough job of investigating the initial-condition bias:
  - Bias is not affected by the number of replications, instead, it is affected only by deleting more data (i.e., increasing T_0) or extending the length of each run (i.e. increasing T_E).
  - Basic raw output data $\{Y_{rj}, r = 1, ..., R; j = 1, ..., n\}$ is derived by:
    - Individual observation from within replication *r*.
    - Batch mean from within replication *r* of some number of discrete-time observations.
    - Batch mean of a continuous-time process over time interval *j*.