Disclaimer: I DO NOT claim or guarantee whether the answer written here is 100% accurate. If you feel something is not accurate or out-of-order, it will be a great help, if you let me know. You know how to find me.
I Do Not recommend this note for your exam. Its too raw. Use the note provided by Sir.
Note: Those question which are crossed (i.e. strike-through) refer to the repeated question which has been already solved/answered.
Tips: Don't try to read this pdf using mobile. Its hard & time consuming. Use your laptop. Read it in full-screen format.

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2023 Fall

1 a) Define system simulation. Explain different types of model.
1 b) What do you mean by Monte Carlo method? Estimate the value of $\int_2^5(4x)\,dx$ using monte carlo method.
2 a) What are the steps involved in computer simulation. Explain with neat diagram.
2 b) Draw Cobweb model for the following market economy. Explain in breif:

$D = 12.4 – 1.2P$
$S = 9 – 0.5P_{-1}$
$P = 1.0$ (Assume market is clear.)

3 a) Explain the data and control statement in CSMP III. Explain with example.
3 b) Describe the measuring utilization and occupancy with mathematical modeling.
4 a) Calls are lost when lines are busy or link is not free. Explain various steps involved to simulate this system.
4 b) The following numbers have been generated 0.54, 0.73, 0.98, 0.11 and 0.68. Use the kolmogoror (smirnov) test to check whether given numbers are uniformity distributed or not. Use critical value of D for ∞ = 0.05 and N = 5 is 0.565.
5 a) Define analog computer with its components in detail. Draw and explain a block diagram using analog method for solving the Analog computer model of liver.
5 b) Worker come to a supply store at the rate of one every 7±3 minute. Their requirements are processed by one of the two clerks who take 10±5 minutes for each requisition. The requisition are then passed to a single storekeeper who fills them one at time, taking 6±3 minutes for each request. Draw the GPSS block diagram to simulate the queue of workers and measure the distribution of time taken for 500 requisitions to be filled.
6 a) Define SIMSCRIPT. Explain the SIMSCRIPT execution cycle in details.
6 b) Define Calibration. Explain various technique of Elimination of Initial bias with examples.
=>

Initial bias, also known as the startup problem or the initialization bias, is a common issue in simulation studies. It refers to the bias introduced in the simulation results due to the initial conditions or the transient behavior of the system before it reaches a steady state. Here are some techniques to eliminate initial bias:

i. **Warm-up Period (Initial Data Deletion)**:
- This technique involves running the simulation for an initial period, called the warm-up period, and discarding the data generated during this time.
- The warm-up period allows the system to reach a steady state before collecting data for analysis.
- Example: In a simulation of a manufacturing process, the warm-up period could be the time required for the machines to reach their normal operating conditions and for the system to stabilize.

ii. **Initial State Approximation**:
- Instead of starting the simulation from an empty or idle state, this technique involves setting the initial conditions close to the expected steady-state conditions.
- By starting the simulation in a more representative state, the initial bias can be reduced.
- Example: In a simulation of a hospital emergency department, the initial state could be set with a certain number of patients already in the system, based on historical data or expert knowledge.

iii. **Intelligent Initialization**:
- This technique uses domain knowledge or heuristics to determine appropriate initial conditions for the simulation.
- By setting the initial state intelligently, the simulation can converge to the steady state more quickly, reducing the initial bias.
- Example: In a simulation of a computer network, intelligent initialization could involve setting the initial buffer sizes and packet rates based on known traffic patterns and network characteristics.

iv. **Batch Means Method**:
- This technique divides the simulation output into batches or subsets of equal size.
- The initial bias is reduced by discarding the first few batches and using the remaining batches for analysis.
- Example: In a simulation of a call center, the output data could be divided into hourly batches. The first few hours of data, which may be affected by initial bias, are discarded, and the remaining hourly batches are used for analysis.

v. **Replicated Runs**:
- This technique involves running multiple independent replications of the simulation with different random number streams.
- The initial bias is reduced by averaging the results across the replications, as the impact of the initial conditions is diminished.
- Example: In a simulation of a supply chain, multiple replications could be run with different random demand patterns. The average performance measures across the replications provide a more accurate estimate of the system's behavior.

It's important to note that the choice of the appropriate technique depends on the specific characteristics of the simulation model and the available data. A combination of techniques may be used to effectively eliminate initial bias and obtain reliable simulation results.

7. Write short notes on: (**Any two**)
a) Pseudo random number
b) Predator Pray Model
c) Estimation Methods

2023 Spring

1 a) Define simulation. Explain different types of model.
=>

Simulation is a model that mimics the operation of an existing or proposed system, providing evidence for decision-making by being able to test different scenarios or process changes.

Types of Models
Different types of model are
- Mathematical Model or Physical Model
- Static Model or Dynamic Model
- Deterministic Model or Stochastic Model
- Discrete Model or Continuous Model

1 b) What do you mean by Monte Carlo method? Estimate the value of $\int_2^5 5x$ using Monte Carlo method. (Use 15 samples)

2 a) **What are types of system simulation?** Explain the steps involves in simulation study.
Ans:
Different types of System Simulation are:
i. Discrete System Simulation
ii. Continuous System Simulation

2 b) What is CSSL? Write CSMP III code for automobile suspension wheel.

3 a) Draw the analog model of the Liver with following set of equations:
$dx_1/dt = -k_{12}x_1 + k_{21}x_2$
$dx_3/dt = k_{23}x_2$
$dx_2/dt = k_{12}x_1 – (k_{21} + k_{23})x_2$

3 b) Calls are lost when lines are busy or link is not free. Explain various steps involved to simulate this system.
4 a) How is statistics gathered in simulation? Explain with reference to telephone system.
4 b) Using Additive Congruential, find the period of the generator and set of random numbers for a=5, c=7, m=64 and seed X_0 = 5.

5 a) Using Chi-Square test with α = 0.05, check for the uniformity of the given random no.

0.89	0.69	0.12	0.83	0.60	0.95	0.01
0.93	0.27	0.58	0.23	0.99	0.75	0.19
0.28	0.15	0.88	0.36	0.89	0.33	0.63
0.31	0.35	0.49	0.64	0.91	0.05	0.27
0.41	0.43					

5 b) Patients are arriving at the clinic with the interval time from 6 to 10 minutes. The patients take 3 minutes to reach the doctor room. The patient has to wait in a queue if the doctor found to be busy otherwise the doctor takes about 8 to 10 minutes for examining each patient. Draw GPSS block diagram and write a code to simulate for 200 patients check by the 5 doctors.

6 a) Explain the SIMSCRIPT execution cycle in details with diagram.
6 b) Define Estimation method. What are the problems occurred during simulation Run statistic? Explain how it can be maintained?
7. Write short notes on:
a) Time advancement mechanism
b) Elimination of initial bias
c) Utilization and Occupancy

2022 Fall

1 a) What is simulatation and model? Explain various models that are involved while simulating system.

1 b) Why Monte-Carlo method is best method for computing static method? Use it to solve $\int_2^6 x^2\,dx$ using 10 samples. **Also estimate the error percentage.**
Solution:

Let, $y = \int_2^6 x^2$ ∴ f(x) = y

See this video:
https://www.youtube.com/watch?v=zueAHdERkzE

when, x = 2, than $y = 2^2 = 4$
when, x = 6, than $y = 2^6 = 64$

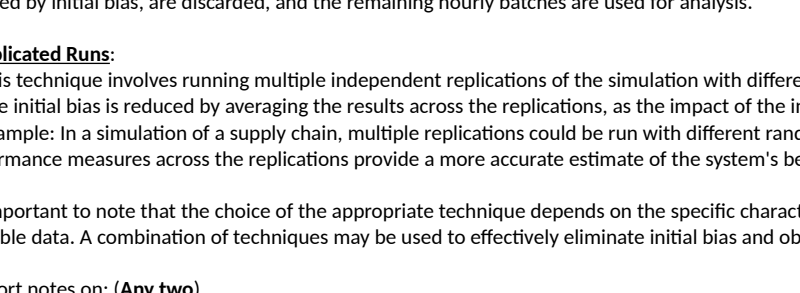
==

2 a) Draw a Cobweb model for the following market economy. Explain in brief.
$D = 12.4 – 1.2P$
$S = 9 – 0.5P_{-1}$
$P = 1.0$ (Assume market is clear.)

==

2 b) Draw the analog model of the Liver with following set of equations: -----→ most repeated question
$dx_1/dt = - k_{12}x_1 + k_{21}x_2$
$dx_3/dt = k_{23}x_2$
$dx_2/dt = k_{12}x_1 – (k_{21} + k_{23})x_2$

Solution:



3 a) How does predator-prey relationship affect population growth? Explain with its CSMP III program.

3 b) "Call gets lost when link in not available or line is busy" Verify this statement on the basis of various state involved in this simulation.

==

4 a) How is statistics gathered in simulation? Explain with reference to telephone system.

Statistics are gathered in simulations to analyze the performance and behavior of the system under study. In simulation, statistics are gathered to assess the performance of a method or system, typically when there is a lack of theoretical background. The specific method used to gather statistics in simulation can vary depending on the specific application and context, but some common methods include:

→ **Monte Carlo simulation**: This method involves repeatedly drawing samples from a distribution to do some statistical analysis on an artificial population with known, but random, properties. The purpose of this is to gain insight into the real world and to assess the performance of a method or system.

→ **Bootstrapping**: This method involves generating confidence intervals by resampling the data and calculating the statistic of interest on each resampled data-set. This allows for the estimation of the sampling distribution of the statistic and the calculation of confidence intervals.

→ **Replicated data simulation**: This method involves simulating data that has the same characteristics as the actual data and comparing the simulated results to the actual results. This allows for the assessment of the performance of a method or system on the actual data.

→ **Sensitivity analysis**: This method involves varying the input parameters of a model or system to assess the impact on the output. This allows for the identification of the most important input parameters and the of the robustness of the model or system.

In summary, statistics are gathered in simulation to assess the performance of a method or system. Common methods used to gather statistics in simulation include Monte Carlo simulation, bootstrapping, replicated data simulation, and sensitivity analysis. The specific method used can vary depending on the specific application and context.

In a telephone system simulation, various statistics can be collected as follows:

→ **Call arrival rate**: The number of calls arriving per unit time can be measured. This can be measured for different time periods to analyze call traffic patterns. The call arrival rate is an important input for sizing the number of required servers.

→ **Call waiting times**: The time each call spends waiting in the queue can be measured to analyze the level of service provided. Long waiting times indicate the need for more servers or other improvements.

→ **Number of calls in queue**: The queue length for different time periods can be measured to assess traffic loads and delays. Large queue lengths indicate high traffic loads relative to the serving capacity.

→ **Server utilization**: The fraction of time each server spends busy can be measured to analyze how well the serving resources are being utilized. High utilizations indicate more servers may be needed to handle the load. Low utilizations indicate underutilized resources.

→ **Call lengths**: The duration of calls can be measured to determine the average call length. This can be used to estimate the total load on the system relative to the arrival rate. Longer calls mean fewer calls can be served for the same arrival rate.

→ **Number of abandoned calls**: The number of callers that hang up while waiting in the queue can be measured. This assesses the level of impatience with delays in the system. More abandoned calls indicate the need for reduced waiting times through more servers or other means.

→ **Total time spent on calls**: The total duration of time spent by servers handling calls can be measured to analyze the volume of calls relative to the amount of serving resource. High total times indicate the potential need for more servers to meet the offered load.

These statistics, gathered and monitored over the simulation, can provide valuable insights into the performance, issues, and potential areas of improvement for the telephone system. They quantify the level of service, utilization of resources, traffic loads, delays, etc. which guide decisions on sizing servers, managing traffic, and enhancing the overall quality and capacity of the system.

==

4 b) Define calibration. Explain, why elimination of Initial Bias required?

Calibration refers to the process of adjusting a model to match its outputs to the known values of the real system inputs and outputs. It is done to increase the accuracy and reliability of the model.

Initial bias refers to the differences between the model's outputs and the real system's outputs before the calibration process. These biases exist because the model is an approximation of the real system and simplifies some details and dynamics.

Eliminating the initial bias is important for the following reasons:

→ **To increase the model's accuracy**: By calibrating the model and removing initial biases, the model can produce outputs that closely match the real system. This results in a more accurate model that can be used to predict the system's behavior reliably.

→ **To reduce prediction errors**: With calibration, the errors in the model's predictions can be minimized. The predictions have a higher likelihood of being close to the real values. Without calibration, the initial biases may cause the predictions to be quite off from reality.

→ **To build confidence in the model**: By showing that the model's outputs can match closely to reality after calibration, the confidence in the model's ability can be increased. Users and stakeholders can have more faith that the model is a good representation of the actual system.

→ **To determine the model's parameters**: The calibration process is also used to refine and determine suitable values for the model's parameters so that it can match closely to the real system. The parameter values that produce the closest match are selected.

So in summary, the elimination of initial biases through calibration is crucial to improve a model's accuracy, reduce errors, build confidence in its use, and determine appropriate parameter settings. An uncalibrated model with high initial biases may not be useful or reliable for analysis and prediction.

==

5 a)

Employ the arithmetic congruential method to generate a sequence of 10 random number given r_1 = 987, r_2 = 535 and modulo m = 1000. Perform KS test to check uniformity of the random number under 95% confidence interval.

==

5 b) What is confidence interval? **Explain estimation methods and state Central Limit Theorem.**
Ans:

Chakundan note answer

IID = Independent and Identically distributed variable

In statistics, a confidence interval (CI) is a particular kind of interval estimate of a population parameter and is used to indicate the reliability of an estimate. It is an observed interval (i.e. it is calculated from the observations), in principle different from sample to sample, that frequently includes the parameter of interest, if the experiment is repeated. How frequently the observed interval contains the parameter is determined by the confidence level or confidence coefficient.

Estimation methods

Statistical methods are commonly used on the random variable. Usually, a random variable is drawn from an infinite population with a finite mean 'μ' and finite variance 'σ2'. These random variables are independently and identically distributed (i.e. IID variable).

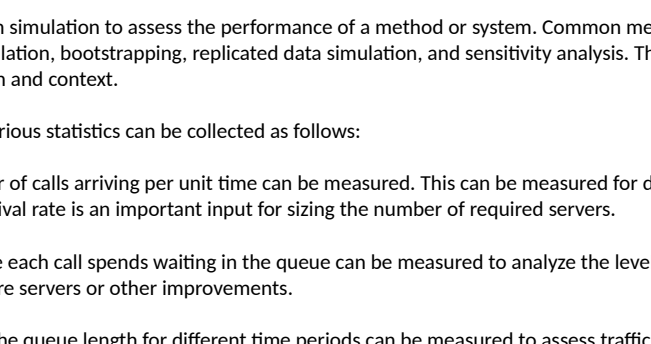
Let, xi = iid random variables, (i = 1, 2, …, n), then according to central limit theoram and applying transformation, approximate normal vairance,

$$Z = \frac{\sum_{i=1}^{n} x_i - n\mu}{\sqrt{n}\sigma}$$

$$Z = \frac{\bar{x} - \mu}{\sigma/\sqrt{n}}$$

where, $\bar{x}$ = sample mean

a. It can shown to be a consistent estimator for the mean of the population from which the sample is done.
b. Since the sample mean is some of the random variables, it is itself a random variable. So, a confidence interval about its computed value needs to be established.
c. The probability density function on the standard normal variable (Z) is shown in the figure below.



The integral formed - ∞ to μ is the probability that Z is less than or equal to μ and is denoted by ϕ (u).

Let us consider the value of u ($u_{\alpha/2}$) such that ϕ(u) = 1 – α.

In terms of sample mean μ, the probability statement can be written as:

$$\text{Prob}\left\{\bar{x} + \frac{\sigma}{\sqrt{n}}u_{\frac{\alpha}{2}} \geq \mu \geq \bar{x} - \frac{\sigma}{\sqrt{n}}u_{\frac{\alpha}{2}}\right\} = 1 - \alpha.$$

Here, the constant 1 − α is a confidence level (usually expressed in percent (%)) and the interval $\bar{x} \pm \frac{\sigma}{\sqrt{n}}u_{\alpha/2}$ is the confidence interval.

Estimation population variance s^2 (not σ^2 which is actual population variance) is given as: $S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$.

Replacing $u_{a/2}$ by $t_n - 2, {}^{\alpha}/_{2}$, then the estimated variance s^2, the confidence interval for $\bar{x}$ is given as: $C = \bar{x} \pm \frac{s}{\sqrt{n}}t_n - 1, {}^{a}/_{2}$

==

6 a) Consider a bank with 3 service counter where customer arrival time is in average of 5 with a variance of 2 minutes. If any customer find the first service counter busy. He/She goes to another service counter, but it takes 3 extra minutes to move into the another service counter, similar condition for reaching to third counter, it takes of 10 minutes to proivde service to provide service to any customer with 2, 3, 4 minutes variance respectively at counter 1, 2 and 3. Develop GPSS model considering 20% customer do not get proper services.

==

6 b) **Explain about the organization of SIMSCRIPT program with suitable example.**

Event routines are closed routines and some means must be provided for transferring control between them. The transfer is affected by the use of event notices which are created when it is determined that an event is scheduled. If the event is to involve one of the temporary entities, of which ~~these~~ there maybe many copies, the event notice will usually identify which one is involved.

The event notices are filled in chronological order. When all events that can be executed at a particular time have been processed, the clock is updated to the time to the next event notice and control is passed to the event routine identified by the notice. These actions are automatic and do not need to be programmed.

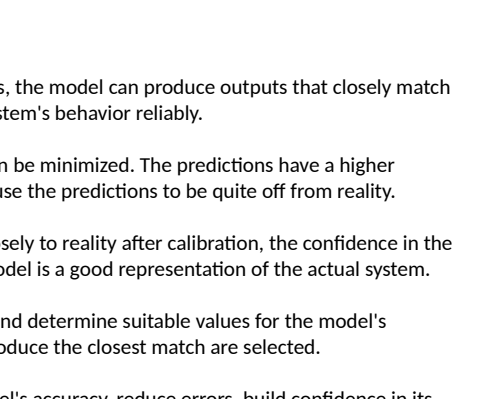


Fig: Simscript Execution Cycle (aka, Lifecyle of Simscript)

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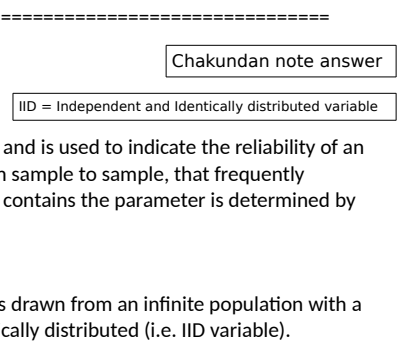
7. Write shorts notes on **any two**:
a. Queue Discipline
b. Principle used in modeling
c. GPSS

==

2021 Spring

1 a) Define Simulation and explain the importance of simulation and its application.
1 b) What are the properties of Monte Carlo integration? Integrate the following using Monte Carlo Method.

$$I = \int_2^6 3x^2\,dx$$



solution:
Let, $y = f(x) = 3x^2$
lower limit (a) = 2
upper limit (b) = 6
When,

x	2	6
y	12	108

Area of rectangle (A) = (b – a) x [f(b) – f(a)] = (6 – 2) x (3x6² – 3x2²) = 384

Suppose, we use N = 5 random (x, y) points using these two condition:
2 ≤ x ≥ 6
12 ≤ y ≥ 108

To know whether (x,y) point fall in or out of the curve:
Let say, $I = \int_a^b x^2$
Then,
$y–x^2≤0$ represents the area **under** the curve $y=x^2$
$y–x^2≥0$ represents the area **above** the curve $y=x^2$
You can use any one method to write the equation.
If a (x,y) points satisfy first equation, it means the points are on or below the curve.
And if (x,y) points satisfy second equation, it means the points are on or above the curve.

(x_1, y_1) = (2, 12)
(x_2, y_2) = (3, 24)
(x_3, y_3) = (4, 50)
(x_4, y_4) = (5, 80)
(x_5, y_5) = (6, 100)

Now,
We can write the equation of curve as:
$y \leq 3x^2$

Putting value of x and y in above equation to find the number of points that fall inside the curve.

For (2, 12), 12 ≤ 12 is true. So accepted.
For (3, 24), 24 ≤ 27 is true. So accepted.
For (4, 50), 50 ≤ 48 is false. So rejected.
For (5, 80), 80 ≤ 75 is false. So rejected.
For (6, 100), 100 ≤ 108 is true. So accepted.

Hence, Total number of point that fall under the curve (M) = 3

Therefore, F = M/N * A = 3/5 * 384 = 230.4 ----------→ Calculated Value

To Calculate % of Error:
Exact Value = $_2\int^6 3x^2$ = [3 * 6²] – [3 * 2²] = 96

% Error = | Exact Value– Calculated value | / Exact Value x 100% = | 96 – 230.4 | / 96 x 100% = 134.4 / 96 x 100% = 140% lol.

==

2 a) **Explain predator prey model with a real life example.**
Ans:
Predator-Prey model is also called the parasite-host model. An environment consists of two population i.e. predator and pray. It is also mathematical model. The prey is passive but the predator depends on the prey for their source of food.

Let x(t) and y(t) is the population of the prey and predator species at any time t.
Now the following assumption for prey and predator model:
- In the absence of predator the population of the prey will grow at the natural rate dx/dt = ax, a>0.
- In the absense of prey the predator population could decrease at the natural rate dy/dt = -py, p>0.
- The presence of both population i.e. predator & prey is benificial to the growth of predator species & is harmful to growth of prey species. i.e. The predator species increases and the prey species decreases at rate proportional to the product of the two population.
- These assumption give the system of non-linear first order ordinary differential equation.

dx/dt = ax – bxt = x (a – by) -----------(i) a,b > 0
dy/dt = –py + qxt = y (qx – p) -----------(ii) p,q > 0

where, a, b, p, q are positive constant; and a & p are the growth rate of prey & death rate of predator respectively.
b and q are major effect of interaction between two species.

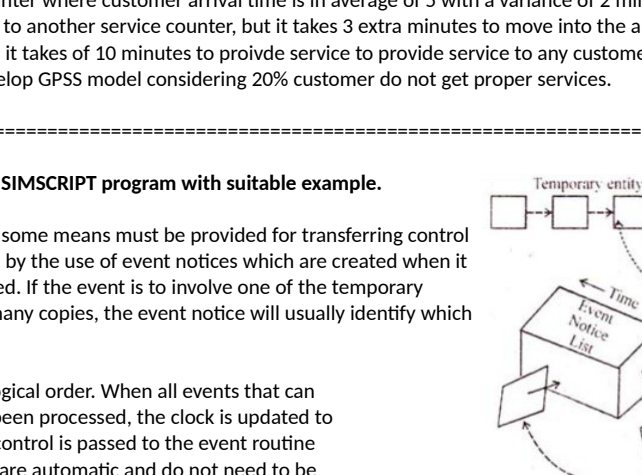


Fig: Predator Prey Model

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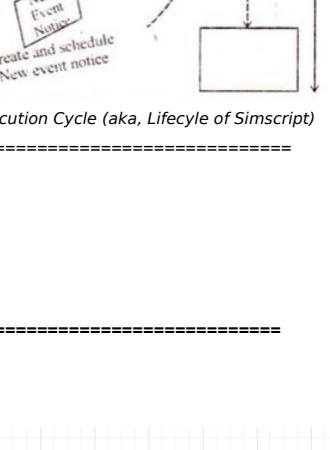
2 b) What is cobweb model? Discuss the ways to measure the performance of a queue.
3 a) How are analog computer different from digital computer? Draw analog computer for the following function:
$ax'' + bx – c\theta = F(t)$
$e\theta'' + f\theta – gx = G(t)$

==

3 b) Describe the simulation of telephone system of lost call system using suitable diagram.

The objective of simulation will be to process given number of call to determine processed, completed, blocked and busy.
There are two activities causing the events:
i. New calls can arrive
ii. Existing calls can finish



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4 a) What is random number? How it is different than pseudo random number? Explain about the technique used to generate a random number.
4 b) Explain in detail with diagram how SIMSCRIPT execution cycle takes place?
5 a) How can time be represented in discrete system simulation. Compare and contrast about utilization and occupancy.
5 b) What type of simulation is suited for GPSS? Give the GPSS block diagram and write GPSS program for the following.
Customer come to a store at the rate of one every 5+-4 minute. Their requisitions are processed by one of three clerks who take 4+-3 minutes for each requisition then are then passed single store keeper who face them one at time taking 7+-3 minutes for each request then customer leave the store.

6 a) Explain the types of simulation on the basis of output. **Define and explain estimation methods used in analysis of simulation output.**

[YouPro AI]

Estimation Methods

Estimation methods are statistical techniques used to infer the properties of a larger population from a smaller sample. These methods are crucial because they allow researchers to make predictions and decisions without needing to survey an entire population, which is often impractical or impossible.

Central Limit Theorem (CLT)

The Central Limit Theorem is a fundamental concept in the field of statistics and plays a critical role in estimation methods. It provides the foundation for making inferences about population parameters based on sample statistics.

Explanation of the Central Limit Theorem

The CLT states that when independent random samples are taken from any population with a finite level of variance, the distribution of the sample means will tend to follow a normal distribution as the sample size becomes larger, regardless of the shape of the population distribution. This is significant because the normal distribution has well-known properties that allow for easier calculation of probabilities and confidence intervals.

The theorem holds true even if the original population is not normally distributed, which is quite remarkable. As the sample size increases, the sampling distribution of the sample mean becomes increasingly normal. This is why the CLT is so widely applicable; it allows for normal approximation in a variety of situations.

6 b) What is initial bias. Discuss the ways to eliminate it.
7. Write short notes on **any two**:

a. **Chi-square Test**
The chi-square test is very important and useful test to determine how often certain observed data fit the theoretical expected value.

$$X_0^2 = \sum_{i=1}^{h} \frac{(Oi – Ei)^2}{Ei}$$

where,
Oi = Observed number in i^{th} class
Ei = Expected number in i^{th} class
n = No. of classes

Chi-Square Test
One procedure for testing the hypothesis that a random sample of size *n* of the random variable *X* follows a specific distributional form is the chi-square goodness-of-fit test.
· This test formalizes the intuitive idea of comparing the histogram of the data to the shape of the candidate density or mass function, The test is valid for large sample sizes, for both discrete and continuous distribution assumptions, When parameters are estimated by maximum likelihood.

Where **0i**, is the observed frequency in the ith class interval and **Ei**, is the expected frequency in that class interval. The expected frequency for each class interval is computed as **Ei = npi**, where **pi** is the theoretical, hypothesized probability associated with the ith class interval.
It can be shown that approximately follows the chi-square distribution with k-s-1 degrees of freedom, where s represents the number of parameters of the hypothesized distribution estimated by sample statistics. The hypotheses are:
H0: the random variable, X, conforms to the distributional assumption with the parameter(s) given by the parameter estimate(s)
H1: the random variable X does not conform
If the distribution being tested is discrete; each value of the random variable should be a class interval, unless it is necessary to combine adjacent class intervals to meet the minimum expected cell-frequency requirement. For the discrete case, if combining adjacent cells is not required,

Pi = P(XI) = P(X =Xi)

Otherwise, **pi**, is determined by summing the probabilities of appropriate adjacent cells.
If the distribution being tested is continuous, the class intervals are given by [ai-1,ai), where **ai-1** and **ai**, are the endpoints of the *ith* class interval. For the continuous case with assumed pdf f(x), or assumed cdf *F(x)*, pi, can be computed By

Pi= ∫ f(x) dx= F(ai) – F(ai -1)

==

b. Real time simulation
c. Verification and Validation of model

2021 Fall

1 a) How do we define system, model and simulation? ~~List out various types Models~~ and explain any one of models with example.

1 b) How can simulation clock be advanced? Explain in details with example.

2 a) **For the case of n=6 arrivals occur at times 0.7, 1.3, 2.5, 3.9, 4.5, 5.6, 5.9 and 7.5. Departure occurs at 2.6, 3.2, 3.5, 5.1 and 8.9 and the simulation ends at time T (6) = 8.6. Estimate the utilization of server and write the equation to represent server utilization.**

2 b) Explain Predator-Prey Model with a real life example.
3 a) What is non-linear differential equation? Explain the model used to represent this type of equation.
3 b) Why do we need to gather statistics? Explain about utilization and occupancy in simulation.
4 a) Make the necessary assumption and explain the various steps in simulation telephone call model when they maintain queue list when line are busy.

4 b) How variable, temporary entities, permanent entities and event notices can be declared in SIMSCRIPT language? How variables can be referenced?

==

5 a) Define pseudo-random numbers. The following numbers have been generated 0.44, 0.19, 0.88, 0.27, 0.55, 0.13, 0.63, 0.74, 0.11 and 0.33 determine, if the hypothesis that the numbers are uniformly distributed on the interval [0,1] can be rejected. (Note that the critical value of D for alpha=0.05 and N=10 is 0.410).

Extra Notes
-> R_i is random number.
-> R_i = i^{th} is the smallest integer.
-> H_0 = R_i ~ U [0,1] means H_0 is hypothesis where R_i is uniformly distributed in interval [0,1].
-> H_1 = R_i ~ U [0,1] means H_1 is hypothesis where R_i is not uniformly distributed in interval [0,1].
-> D^+ max { (i/N)-R_i }, 1 ≤ i ≤ N
-> D^- max { R_i – (i-1)/N }, 1 ≤ i ≤ N

(my thought:
N=10 is typing mistake. It should be μ=10.
μ mean **Critical Value**)

Solution:
Step 1: Define Hypothesis
H_0= R_i ~ U [0,1]
H_1= R_i ≁ U [0,1]

Step 2: Arrange number in increasing order
0.11, 0.13, 0.19, 0.27, 0.33, 0.44, 0.55, 0.63, 0.74, 0.88

Step 3: Compute D+, D- and D where N = 10.

i	1	2	3	4	5	6	7	8	9	10
R_i	0.11	0.13	0.19	0.27	0.33	0.44	0.55	0.63	0.74	0.88
i/N	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
(i/N) - R_i	-	0.07	0.11	0.13	0.17	0.16	0.15	0.17	0.16	0.12
R_i - [(i-1)/N]	0.11	0.03	-	-	-	-	-	-	-	-

D^+ = max { 0.07 , 0.11, 0.13, 0.17, 0.16, 0.15, 0.17, 0.16, 0.12 } = 0.17
D^- = max { 0.11, 0.03 } = 0.11

Writing the i/N column is optional.

Then,
D = max { 0^+, 0^-} = max { 0.17, 0.14 } = 0.17

Step 4: Calculate critical value for α = 0.05 and N = 10
$D_{\alpha,N} = D_{0.05,10}$ = 0.410 --------→ already given in the question. *[If not given in question, than use "Statistical Table" in exam.]*

Step 5: Conclusion
Here, calculated D = 0.17 is smaller than Critical Value $D_{\alpha,N}$= 0.410.
Therefore, H_0 is accepted. Hence, the numbers are uniformly distributed.

==

5 b) Define GPSS and its need. **Explain various facility and storage Blocks used in GPSS simulation system.**
==>
Facilities and Storages
- Facilities and Storages are permanent entities that operates on the transactions.
- Facility is defined as an entity that can be **engaged by a single transaction at a time**.
- Storage is defined as an entity that can be **occupied by many transactions at a time** up to some predefined limit.
- A transaction controlling a facility can be interrupted or preempted by another transaction.
- Both facilities and storages can be made unavailable if the equipment they represent breaks down and made available again if repaired
- Entities are numbered starting from 1

Example:

Type of system	Transaction	Facility	Storage
Communications	Message	Switch	Trunk
Transportation	Car	Toll booth	Road
Data Processing	Record	Key punch	Computer Memory

```
        GENERATE    5
        SEIZE  1
        ADVANCE     4,3
        RELEASE     1
        TRANSFER    0.1,ACC,REJ
ACC     TERMINATE   1
REJ     TERMINATE   1
```

E.g. program: Using facility only. Get one inspector.

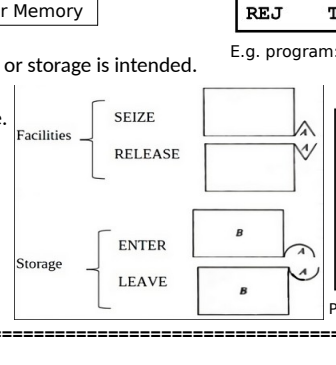
In SEIZE, RELEASE, ENTER, LEAVE blocks, field 'A' indicates which facility or storage is intended.

→ **SEIZE** block allows the transaction to engage a facility if it is available.

→ **RELEASE** block allows the transaction to disengage the facility.

→ **ENTER** block allows a transaction to occupy space in storage.

→ **LEAVE** block allows it to give up the space.




```
myStorage    STORAGE     3

Beg     GENERATE    5
        ENTER       myStorage
        ADVANCE     12,9
        LEAVE       myStorage
        TRANSFER    0.1,ACC,REJ
ACC     TERMINATE   1
REJ     TERMINATE   1
```

Program: Using Storage. Get three inspector.

==

6 a) The results of simulation can be random. For random output which method is suitable and how can they be analyzed. Explain in detail.
6 b) When simulation is preformed multiple times with varying parameter the output produced are random. In such case which of the method can be used to analyze the results, explain.
7 Write shots notes on:

a) Simulation versus Analytical Method

Simulation method	Analytical method
It is the process of using a model to study the behaviour and performance of an actual or theoretical system.	It is a mathematical abstraction that can be extended to address various working conditions, thanks to some assumptions about the way a process is evolving.
It is used when an analytical formulation cannot be derived (for example when the size of the model is too large,or when no exact solution can be derived).	It is used the there are enough data about system to research.

b) ~~Chi-square Test~~
c) Bootstrapping Method

Spring 2020 [Online]

1. ~~Discuss about different types of model.~~ Explain the steps involved in the verification and validation of model.

==

2. Explain the Distributed lag model in detail and **Draw and explain a Cobweb model for the following market**:
$D = 12.4 – 1.2 P$
$S = 9.0 – 0.6 P_{-1}$
$P_0 = 1.0$ (Assume market is clear.)

#Extra_Note
Supply is has P_{-1} in its equation, this means it is a **Lagged Supply Equation**.
Demand has no subscript in its equation, it mean it's a **Unlagged Demand Eq**ⁿ.

Sol:
From question:
D = 12.4 – 1.2 P -----→ Q_d = α – β (P) -----→ Than, α = 12.4 β = 1.2
S = 9.0 – 0.6 P_{-1} -----→ Q_s = γ - δ P_{-1} -----→ Than, γ = 9 δ = 0.6
We know,
At equilibrium condition:
Demand (D) = Supply (S)
Than,
12.4 – 1.2 P = 9.0 – 0.6 P_{-1}
0.6 P_{-1} – 1.2 P = 9.0 – 12.4
0.6 P_{-1} – 1.2 P = –3.4
1.2 P – 0.6 P_{-1} = 3.4
Normalizing by dividing throughput by 1.2:
P – 0.5 P_{-1} = 2.83 ------- (iii)
Since,
Initial Price (P_0) = 1.0, than the demand when price is 1, is : D = 12.4 – 1.2 x 1 = 11.2
Putting
…….

==

3. ~~Explain the three general types of statements in CSMP III?~~ Derive a CSMP III program for the automobile suspension problem and also draw a block diagram using analog method for solving the following model.
F(t) = MX'' + DX' + KX.

Solution:
Wheel suspension of the automobile is one example of **Continous System Simulation**.
Sovling the equation for the highest order derivates gives: MX'' = F(t) - DX' - KX

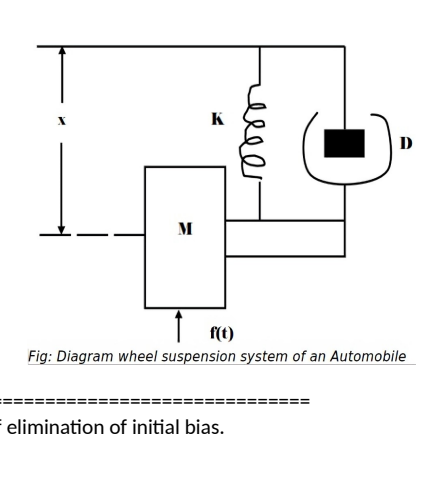


Fig: Diagram wheel suspension system of an Automobile

==

4. Describe initial bias. How it affects the output of simulation. Explain in detail various techniques of elimination of initial bias.

OR

Test the **auto correlation** of random numbers using significance level of 99% on the following sequence of random numbers.
0.13, 0.21, 0.23, 0.32, 0.19, 0.93, 0.89, 0.73, 0.99, 0.33, 0.27, 0.35, 0.28, 0.65, 0.56, 0.42, 0.87, 0.69, 0.37, 0.18, 0.88, 0.25, 0.05, 0.68, 0.43, 0.75, 0.33.

5. Consider a telephone system which has 10 telephones lines and 4 maximum number of links out of which 2 are in use. Suppose arrival time of first call is 1045. Now explain the simulation of lost call and delayed call considering this case with suitable diagram.

Group 'B': Problem-solving/case studies (20)

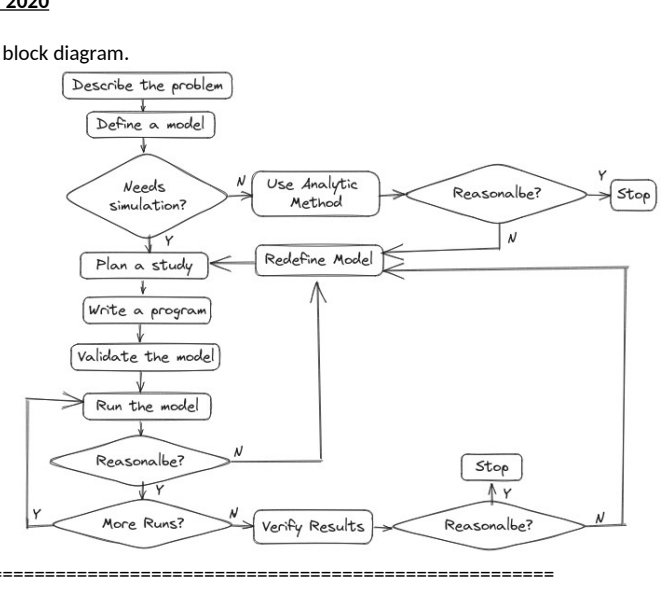
6. Read the case situation given below and answer the questions that follow:

Consider a XYZ bank with 3 service counter where customer arrival time is in average of 5, with a variance of 2 minutes. If any customers 1 of 2 find the first service counter busy, he/she goes to another services counter but it takes 3 extra minutes to move into the another service counter, similar condition for reaching third counter. It takes average of 10 minutes to provide service to any customer with 2, 3, 4 minutes variance respectively for all counters 1, 2 and 3.

Questions:
a) Develop a GPPS model considering 20% customers do not get proper services. [9]
b) Write a SIMSCRIPT program for the above case. [8]
c) Name entities, attributes, activities, events and state variable for the above XYZ banking system. [3]

Fall 2020

1 a) What is simulation and modeling? Explain **steps of simulation** using block diagram.
==>
Steps of Simulation using block diagram



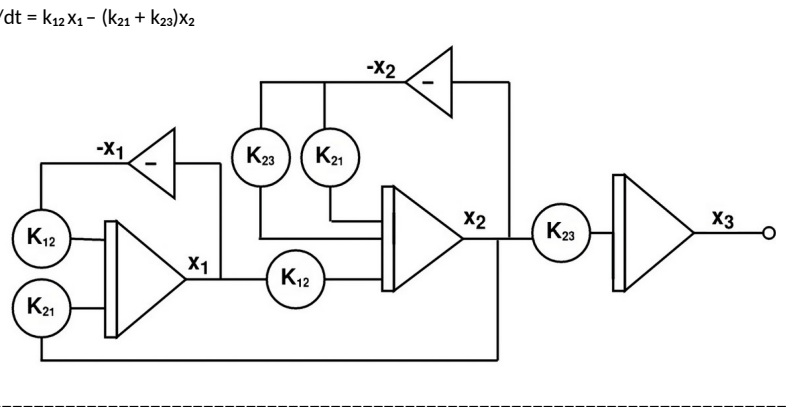
==

1 b) What is Monte Carlo method? Explain with suitable example.
2 a) Explain about Single Server Queuing Model. What are the performance measures of the queues?
2 b) ~~What is CSMP III? Explain the three general types of statements with example.~~

3 a) Draw the analog model of the Liver with following set of equations:

$dx_1/dt = - k_{12}x_1 + k_{21}x_2$
$dx_3/dt = k_{23}x_2$
$dx_2/dt = k_{12}x_1 – (k_{21} + k_{23})x_2$

solution:



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3 b) Describe the simulation of telephone system of lost call system using suitable diagram.
4 a) What is the role of gathering statistics in discrete simulation? Explain.
4 b) What are the properties of random number? **Describe any one random number algorithm to generate pseudo numbers with example.**
==>
All computer generated random no. are called pseudo random no. because they are not truely random. There are different methods to generate pseudo random numbers. Some of them are listed below:

i) **Linear congruence generator**(LCG)
- Mixed congruence generation
- Additive congruence generation
- Multiplicative congruence generation
- Arithmetic

ii) Mid-square method
iii) Inverse transformation method
iv) Rejection method

Linear Congruence Generation aka, **Linear Congruential Generator**
It produces the sequence of integer x_1, x_2 - - - - - between 0 and m-1 may following by recursive relationship

$X_{i+1} = (ax_i+c) \bmod m$ where, i = 0,1,2,……….,m-1.

The initial value x_0 is called the seed; a is called multiplier; c is called increment and m is modulus:

- If c≠0, then the form is called mixed congruential generator.
- If c=0, then the form is called multiplicative congruential generator.
- If a=1, then the form is called additive congruential generator.

Example: **Q1: Generate 4 digit random number by LCG with x_0=21, a=34, c=7.**

Ans: Given generating 4-digit random number i.e. m=10000 and X_0=21, a=34, c=7.

X_1= (ax_0+c) mod m=(34*21+7) mod 10000= 721

R_1= X_1/m =721/10000=0.0721

X_2= (ax_1+c) mod m=(34*721+7) mod 10000=4521

R_2= X_2/m =4521/10000=0.4521

X_3= (ax_2+c) mod m=(34*4521+7) mod 10000= 3721

R_3= X_3/m= 3721/10000=0.3721

X_4= (ax_3+c) mod m=(34*3721+7) mod 10000=9311

R_4= X_4/m =9311/10000=0.9311

I think, Calculation of modules after R_1 are all wrong. X_2=521 then, R_2=0.0521
X_3=721 then, R_3= 0.0721 -----------?? (can't be random number when it is repeated)

==

5 a) Differentiate facilities and storage in detail. Draw a block diagram of a simple manufacturing shop model having more than one inspector.
5 b) What is SIMSCRIPT? Explain SIMSCRIPT program execution cycle with necessary diagrams.
6 a) What is Replication of Run? Explain the idea of elimination of initial bias.

6 b) Using the additive congruential, find the period of the generator and set of random numbers for a=5, c=7, m=64 & seed X_0=5.
==>
solution:
Given:
a = 5
c = 7
m = 64
seed x_0 = 5
Now,
Random number (Ri) = x_i / m
Random number generated will be between (0 – 63).
Equation = x_i -

==

7. Write shorts on **any two**:

a) **Application of Simulation**
Application areas where simulation plays a role are enlisted down below:
- Designing and analyzing manufacturing systems
- Evaluating military weapons systems or their logistics requirements
- Determining hardware requirements or protocols for communications networks
- Determining hardware and software requirements for a computer system
- Designing and operating transportation systems such as airports, freeways, ports, and subways
- Evaluating designs for service organizations such as call centers, fast-food restaurants, hospitals, and post offices
- Re-engineering of business processes
- Analyzing supply chains
- Determining ordering policies for an inventory system
- Analyzing mining operations

==

b) **Feedback System**
Feedback occurs when outputs of a system are routed back as inputs as part of a chain of cause-and-effect that forms a circuit or loop. The system can then be said to feed back into itself. The notion of cause-and-effect has to be handled carefully when applied to feedback systems. This is of two types : -
1.Positive feedback
2.Negative feedback.

Positive feedback occurs when the rate of a process increases as the concentration of the product increases. Negative feedback controls the rate of a process to avoid accumulation of a product. The rate of a process will continuously accelerate under positive feedback as long as substrate is available and the product is not consumed by some other process.

==

c) Estimation Method

==

Fall 2019

1 a) Why do we need to simulate a system? Compare Stochastic with Deterministic Simulation System.
Ans:

Why simulate?
Simulation and modeling needs imagination and innovations to be developed from scratch. Yet, simulation is needed and hence the question "why do we simulate?" Simulation allows experimentation rather than direct, costly, time-consuming experimentation. Simulation allows time control where the user can compress and expand time element. Simulation experiments can be replicated, so as to answer questions like "why did this happen?". Simulation allows the user to explore different possibilities while identifying constrains and predict obstacles. Playing with what-if scenarios, simulation is used to train pilots as well as medical professionals in the case of new technology.

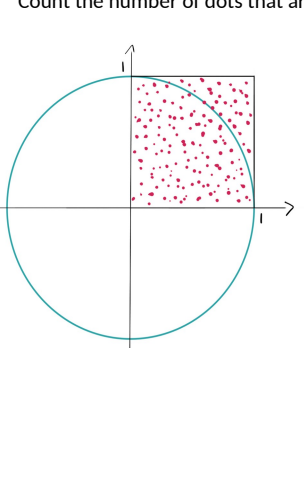
1 b) Monte-Carlo method is numerical computation method. Explain how and use it to determine the value of PI.
Ans:

Monte-Carlo Simulations are experiments or computational algorithms that rely on sampling of random numbers. An experiment or a simulation of random numbers is repeated a large number of times to estimate something that may be determined deterministically as well (such as π, as it is a deterministic number, i.e. it does not depend on randomness or chance). One of the basic examples of getting started with the Monte Carlo algorithm is the estimation of Pi.

Pi is the famous circle number approximately given by 3.14159…

There are different ways to calculate value of pi using Monte-Carlo. We'll use the **easiest way** to find the value of pi.

Draw a unit square and randomly (uniformly distributed) draw any amount of dots on it.
Count the number of dots that are within a distance of 1 from the origin, i.e. within the circle as shown here.



The area A_s of the little square in the first quadrant is given by
Area of square (A_s) = l^2

The area A_c of one-fourth of the unit circle is given by
Area of circle (A_c) = $\frac{1}{4}$ x (area of circle) = $\frac{1}{4}\pi r^2$ = $\frac{1}{4}\pi \times 1^2$ = $\frac{1}{4}\pi$

Thus we can calculate π using the ratio of two areas A_c and A_s

$$\frac{A_c}{A_s} = \frac{1}{4}\pi$$

$$\therefore \pi = \frac{4A_c}{A_s}$$

Note:
Area of circle: πr^2
Perimeter of circle: $2\pi r$
Area of square: l^2

Now,

Let's estimate π by four times the ratio of A_c to A_s. For example if we draw 100 dots and 76 of them end up within the quarter circle, π is approximated by:

$$\pi \approx 4 \times \frac{76}{100} \approx 3.04$$

Not too bad, isn't it? If we for example now draw 1000 dots and 780 of them lie within the quarter circle, this approximates π by

$$\pi \approx 4 \times \frac{780}{1000} \approx 3.12$$

which is even better. We can make this more accurate by drawing more and more dots because thanks to the law of large numbers, we will eventually come very close to π. Thus, we have successfully estimated the value of π using randomness through Monte Carlo method.

---

2 a) Explain Predator-Prey model with example.

---

2 b) Draw block diagram for these equations:

$dx_1/dt = -k_{12}x_1+k_{21}x_2$
$dx_3/dt = k_{23}x_2$
$dx_2/dt = k_{12}x_1-(k_{21}+k_{23})x_2$

~~**3 a) Define CSMP III and explain the types of statement.**~~

---

3 b) What do you mean by analog computer? Explain its advantage and disadvantage.

---

4 a) "Call gets lost when link is not available or line is busy" Verify this statement on the basis of various states involved in this simulation.

---

4 b) What do you mean by uniformity test? Explain the process of uniformity test of random numbers by K-S test method.
=>

TESTS FOR RANDOM NUMBERS

- Uniformity
- Independence

UNIFORMITY:

Frequency Test:

It uses Kolmogorov-Smirnov or the Chi-square test to compare the distribution of the set of numbers generated to a uniform distribution.

OR

Using the linear congruential, find the period of the generator and set of random numbers for a=5, c=1, m=8 and seed x_0=3.

---

5 a) What are the types of simulation language? Explain the feature of simulation language.

---

5 b) What is confidence interval? Explain estimation methods and state Central Limit Theorem.

A confidence interval (CI) is a range of values that is likely to contain the true population parameter (e.g., mean, proportion) with a certain level of confidence. It helps us estimate the population parameter based on a sample and quantify the uncertainty associated with that estimate.

---

6 a) Differentiate facilities and storage's in details. Draw a block diagram of a simple manufacturing shop model having more than one inspector.

---

6 b) What is SIMSCRIPT? Explain SIMSCRIPT program orientation?

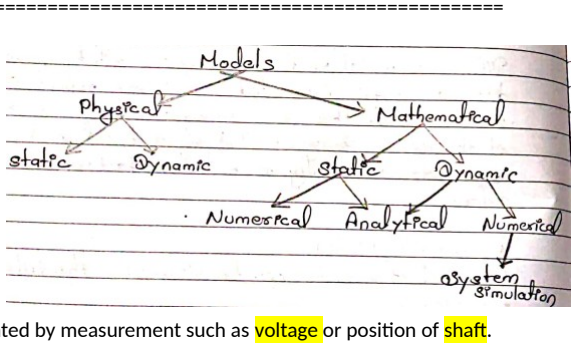
---

7. Write short on any two:
a) ~~Pseudo Random Number~~
b) ~~Utilization and occupancy~~
c) Estimation Methods

Fall 2018

1 a) What is system simulation? Explain types of model.
=>

Systems simulation is a set of techniques that use computers to imitate the operations of various real-world tasks or processes through simulation.



Physical Model	→ In this model of a system, the system attributes are presented by measurement such as voltage or position of shaft.
Mathematical Model	→ This model uses symbolic notation and the mathematical equations to represent a system. Attributes are represented by variables & activities are represented by mathematic function that inter-relates variables.
Static Model	→ Represents a system at a particular point of time. E.g. Monte-Carlo simulation. This model can only show the values that the system attributes takes when system is in balance.
Dynamic Model	→ Represents systems as they change over time. E.g. Simulation of a bank
Deterministic Model	→ Contains no random variables. They have a known set of inputs which will result in a unique set of outputs. E.g. Arrival of patients to the Dentist at the scheduled appointment time.
Stochastic Model	→ Has one or more random variable as inputs. Random inputs leads to random outputs. E.g. Simulation of a bank involves random inter-arrival and service times.
Discrete Model	→ Represent a system which is affected by the state variable which changes at a discrete point of time. E.g. Customer arriving in bank
Continuous Model	→ Represent a system which is affected by the state variable which changes continuously as a function with time. E.g. Increase of water level in tank

---

1 b) ~~What do you mean by Monte Carlo method?~~ Estimate the value of $\int_2^5 x^3 dx$ using Monte Carlo Method.
==>

2 a) Use a cobweb model to investigate a market in which the supply and demand are: [Warning: AI is used on this answer.]

D = $(17.91/p^{1/2})$ - 4.66
9s= 5.0(p_{-1} - 1)

Assume the market is always cleared.

Sol:

At equilibrium state:

Demad (D) = Supply (S)

$$\left(\frac{17.91}{p^{1/2}}\right) - 4.66 = \frac{5.0(p_{-1}-1)}{9}$$

First, let's solve for p in terms of p_{-1}:

$$\left(\frac{17.91}{p^{1/2}}\right) - 4.66 = \frac{5.0(p_{-1}-1)}{9}$$
$$\frac{17.91}{p^{1/2}} = \frac{5.0(p_{-1}-1)}{9} + 4.66$$
$$\frac{17.91}{p^{1/2}} = \frac{5.0p_{-1}-5.0}{9} + \frac{41.94}{9}$$
$$\frac{17.91}{p^{1/2}} = \frac{5.0p_{-1}+36.94}{9}$$
$$17.91 = \left(\frac{5.0p_{-1}+36.94}{9}\right)p^{1/2}$$
$$p = \left(\frac{17.91}{\frac{5.0p_{-1}+36.94}{9}}\right)^2$$
$$p = \left(\frac{17.91 \cdot 9}{5.0p_{-1}+36.94}\right)^2$$

Now we have an equation for p in terms of p_{-1}, which can be used to iterate values starting from an initial price p_0 to observe the convergence or divergence of the sequence of prices. This iterative process is the essence of the cobweb model.

To complete the cobweb process, we iterate the price using the equation derived previously. Let's denote the price at time t as p_t and the price at time t-1 as p_{t-1}. The iterative equation is:

$$p_t = \left(\frac{17.91 \cdot 9}{5.0p_{t-1}+36.94}\right)^2$$

We will start with an initial price p_0 and calculate a few iterations to see the behavior of the prices:

Let's choose an initial price, say $p_0 = 1$ (this is arbitrary and the actual behavior should be checked for different initial prices, but we'll start with $p_0 = 1$ for this example):

$$p_1 = \left(\frac{17.91 \cdot 9}{5.0p_0+36.94}\right)^2 = \left(\frac{17.91 \cdot 9}{5.0 \cdot 1+36.94}\right)^2 = \left(\frac{161.19}{41.94}\right)^2 = \left(\frac{161.19}{41.94}\right)^2 = (3.843)^2 = 14.769$$

Now we use p_1 to find p_2:

$$p_2 = \left(\frac{17.91 \cdot 9}{5.0p_1+36.94}\right)^2 = \left(\frac{17.91 \cdot 9}{5.0 \cdot 14.769+36.94}\right)^2 = \left(\frac{161.19}{111.785+36.94}\right)^2 = \left(\frac{161.19}{148.725}\right)^2 = (1.084)^2 = 1.175$$

And then we use p_2 to find p_3:

$$p_3 = \left(\frac{17.91 \cdot 9}{5.0p_2+36.94}\right)^2 = \left(\frac{17.91 \cdot 9}{5.0 \cdot 1.175+36.94}\right)^2 = \left(\frac{161.19}{41.815}\right)^2 = \left(\frac{161.19}{41.815}\right)^2 = (3.855)^2 = 14.861$$

It appears that the prices are oscillating. To determine if the prices will converge to an equilibrium price or continue to oscillate indefinitely, we would have to continue this process or analyze the stability of the equilibrium by studying the derivative of the function defining p_t with respect to p_{t-1}. If the absolute value of the derivative at the equilibrium point is less than 1, the system will converge; if it is greater than 1, the system will diverge or oscillate.

If you were to plot the data using the iterative values of p_t we calculated, you would plot the points on a coordinate system where the x-axis represents the time period t (or $t-1$) and the y-axis represents the price p_t. The points you would plot based on the calculations we did would be:

- $(0, p_0) = (0, 1)$
- $(1, p_1) = (1, 14.769)$
- $(2, p_2) = (2, 1.175)$
- $(3, p_3) = (3, 14.861)$

---

2 b) Why do we need Digital-Analog Simulators? Write the function of CSMP III Statements: DELT, FINTIM, PRDEL, OUTDEL.
==>

Digital Analog Simulation (DAS) is a programming technique which makes a digital computer operate much like an analog computer.

....

CSMP III, or Continuous System Modeling Program III is an early scientific computer software designed for modeling and solving differential equations numerically. This enables real-world systems to be simulated and tested with a computer. The function of given CSMP III statements are:

DELT	→	Integration interval
FINTIM	→	Finish time
PRDEL	→	Interval at which to print results
OUTDEL	→	Interval at which to print-plot

These statements are part of the TIMER statement in a CSMP III program, which is used to control the timing of the simulation.

- **DELT:** The DELT statement specifies the time step that will be used in the simulation. The time step is the amount of time that will elapse between each event in the simulation.
- **FINTIM:** The FINTIM statement specifies the end time of the simulation. The simulation will run until the time specified by FINTIM is reached.
- **PRDEL:** The PRDEL statement specifies the frequency with which the simulation results will be printed. The PRDEL statement can be used to print the results of the simulation at every time step, or at specified intervals.
- **OUTDEL:** The OUTDEL statement specifies the frequency with which the simulation results will be saved to a file. The OUTDEL statement can be used to save the results of the simulation at every time step, or at specified intervals.

---

3 a) What is lost call? How can we maintain the calls from being lost? Simulate the telephone system for such calls.

Ans:

A lost calls are those calls when a call get lost because the called party is either engaged or when there is no link available to connect.

We can maintain the calls from being lost by delaying calls until they can be connected. To do this, we need to keep the records of the delayed calls. For that, it is necessary to build another list like the calls-in-progress list.

Recomputing the simulation, the system moves through the first two states exactly as before.

<<< See note for this, because it contain figures >>>

---

3 b) Explain measuring Utilization and occupancy of some entity in discrete system simulation process. What is the key difference between utilization and Occupancy?

Like occupancy, Utilization is calculated as a percentage. However, it differs from occupancy as utilization instead represents the amount of time that advisers spend logged-in, handling and expecting contacts, while present in the contact center.

Utilization answers the question: for what percentage of the time that I pay my advisers are they logged in and assisting or available to assist with a customer activity?

Utilization (%) = (Total Logged-in Time / Total Shift Time) ×100

Utilization is important as input to overhead cost or shrinkage calculations, as it considers 'non-customer-related activities' that still get paid for, but that take the adviser away from servicing a customer.

Occupancy is calculated as a percentage and represents the amount of time that advisers spend on call-related activity while they are logged in and expected to be taking calls. "Call-related activity" includes talk time, hold time and wrap time. It is often referred to as "productive time".

Occupancy answers the question: for what percentage of the time that my advisers are logged in live are they actually busy with a customer activity, or are they available to do more?"

It is typical for a contact center's occupancy to lie between 80 and 85%, and if your occupancy rate is at this level, it is likely that your Resource Planning team are doing a good job. However, if occupancy is consistently higher than 85%, you are risking adviser burnout.

But remember, there is no recommended best-practice benchmark for occupancy, and targets should be set with a goal of continuous improvement in mind, balancing financial/budget requirements with employee needs.

Here are the two equations that most contact centers use to calculate occupancy.

Occupancy (%) = (Total Contact Handling / Time Total Logged Time) ×100

However, these formulas are often presented using the following terminology, although they all equate to the same thing.

Occupancy (%) = (Traffic Intensity (Erlangs) / Raw Advisers) ×100

Occupancy is especially important in schedule design, as it assists with measuring schedule optimization, so as not to have advisers sitting and waiting for calls too often.

---

4 a) Explain differential linear and partial differential linear equations in details.
=>

~~Linear Equation:~~

~~An equation in which the maximum degree of a term is one is called a linear equation. Or we can say that a linear equation that has only one variable is called a linear equation in one variable. A linear equation value when plotted on the graph forms a straight line.~~
~~The general form of a linear equation is ax + b = c, where a, b, c are constants and a0 and x and y are variables.~~
~~For Example:~~
~~x + 7 = 12, 5/2x - 9 = 1, x^2 + 1 = 5, x/3 + 5 = x/2 - 3 are equations in one variable x.~~

~~Here the highest power of each equation is one.~~

~~Partial Equation~~
~~An equation in which the maximum degree of a term is 2 or more than two is called a nonlinear equation.~~
~~For example:~~
~~$3x^2$ + 2x + 1 = 0, 3x + 4y = 5~~
~~these are example of nonlinear equations, because equation 1 has the highest degree of 2 and the second equation has variables x and y.~~
~~The nonlinear equation values when plotted on the graph forms a curve.~~

~~The general form of a nonlinear equation is $ax^2+by^2=c$, $ax^2+by^2=c$, where a, b, c are constants and a0 and x and y are variables.~~
~~When plotted on the graph we get the below curve~~

---

4 b) Write the consequences of properties of random numbers. Explain the runs Test of random numbers with an example.

Properties of random numbers are:

i) A sequence of random numbers, R_1, R_2, R_3... must have two important properties:
- Uniformity, i.e. they are equally probable every where
- Independence, i.e. the current value of a random variable has no relation with the previous values.

~~ii) Each random number R_i is an independent sample drawn from a continuous uniform distribution between zero and one.~~

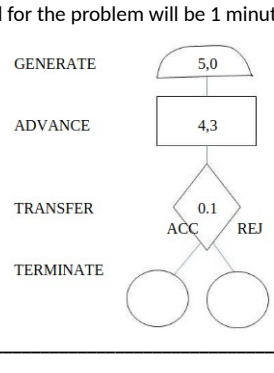
~~iii) Some consequences of the uniformity and independence properties:*~~
- ~~If the interval (0,1) is divided into *n* sub-intervals of equal length, the expected number of observations in each interval is N/*n* where *N* is the total number of observations. Note that *N* has to be sufficiently large to show this trend.~~
- ~~The probability of observing a value in a particular interval is independent of the previous values drawn.~~

---

5 a) Give GPSS block diagram and write program of the following problem:

A machine tool is a manufacturing shop is turning out parts at the rate of one every 5 minutes. As they finished, the parts go to an inspector, who takes 4 ± 3 minutes to examine each one and rejects about 10% of the parts. Each part will be represented by one transaction, and the time unit selected for the problem will be 1 minute.

Solution:




```
GENERATE 5,0              // create parts
ADVANCE 4,3               // inspect parts
TRANSFER 0.1,AAC,REJ      // select or reject
TERMINATE 1               // accepted path
TERMINATE 1               // rejected path
START 1000                // Run for 1000 Parts
```

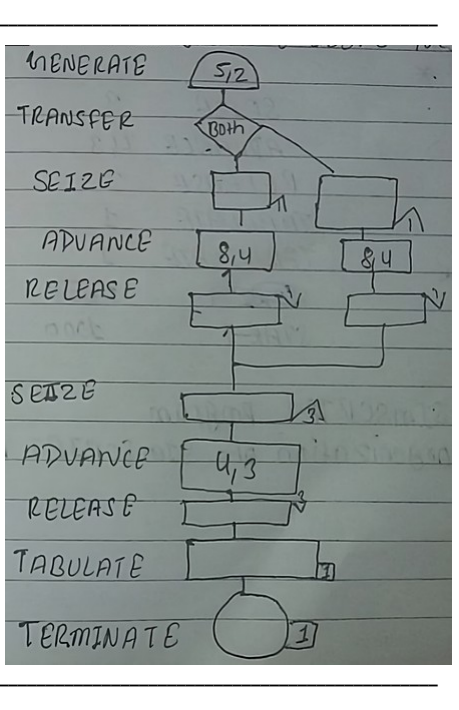
Code : GPSS program for given simualion

---

5 b)

Workers come to a supply store at the rate of one every **5±2** minutes. Their requisitions are processed by one of two clerks who take **8±4** minutes for each requisition. The requisition are then passed to single storekeeper who fills them one at a time taking **4±3** minutes for each request. Write GPSS block diagram and code to simulation above program for 1000 requisitions to filled.

Solution:



---

6 a) What is confidence interval? Explain Estimation methods and state Central Limit Theorem.

The confidence interval is the range of possible values for the parameter based on a set of data (e.g. the simulation results). It helps the user decide whether or not enough simulations have been run. *If the confidence interval is too large for the particular application then it indicates that not enough simulations have been run. The size of the confidence interval will decrease as the number of simulations increases.*

---

6 b) Why gathering of statistics is necessary? Explain utilization and occupancy.

---

7) Write short notes:

a) Discrete probability function Vs Probability density function:

// Question doesn't make any sense.
(question should be: Probability distribution function VS probability density function)

Discrete Probability function	Probability Density Function
~~A discrete probability function is a function that can take a discrete number of values (not necessarily finite). This is most often the non-negative integers or some subset of the non-negative integers~~	

---

7 b) Real time simulation refers to a computer model of a physical system that can execute at the same rate as actual "wall clock" time. In other words, the computer model runs at the same rate as the actual physical system. For example, if a tank takes 10 minutes to fill in the real-world, the simulation would take 10 minutes as well.

In a real time simulation, the simulation is performed in a discrete time with constant step also known as *fixed step simulation* as time moves forward in equal duration of time, other techniques having variable step are used for high frequency transients but are unsuitable for real time simulation. In a real time simulation the time required to solve the internal state equations and functions representing the system must be less than the fixed step. If calculation time exceeds the time of the fixed step, an over run is said to have occurred. In simple words, real-time simulation must produce the internal variables and output within the same length of time as its physical counterpart would.

---

7 c) Distributed lag model: is defined as a type of model that have the property of changing only at fixed interval of time and based on current values of variables on other current values of variables and values that occurred in previous intervals. This model consists of linear algebraic equations that represent continuous system but data are available at fixed points in time. Any variable that can be expressed in the form of its current value and one or more previous value is called lagging variable. And hence this model is given the name distributed lag model.

Advantages of distributed lag model
- Simple to understand and can be computed by hand, computers are extensively used to run them.
- There is no need for special programming language to organize simulation task.

Spring 2018

1 a) "Before system simulation, it is necessary to predict how a system performs its activities", Explain this with the principals of system modeling.
==>

Yes, it is necessary to predict how a system performs before running simulation because simulation is expressive time-consuming process to deal with. Preliminary research on system behaves helps engineers to figure out:
- what kinds of environment the simulation need to be carried. (i.e. endogenous or exogenous)
- why type of simulation should be conducted. (i.e. dynamic, static, etc).
- what input variables should be given. (random or known)

The principal of system modeling are:

i. **Block Building**:
The description of system should be organized in the series of blocks to simplify the specification of interaction within the system. Each block represents a part of system that depends upon a few, preferably one, input variables and results in a few output variables. The system as a whole can then be described in terms of the interconnections between the blocks. Correspondingly, the system can be represented in terms of the interconnection between the blocks.

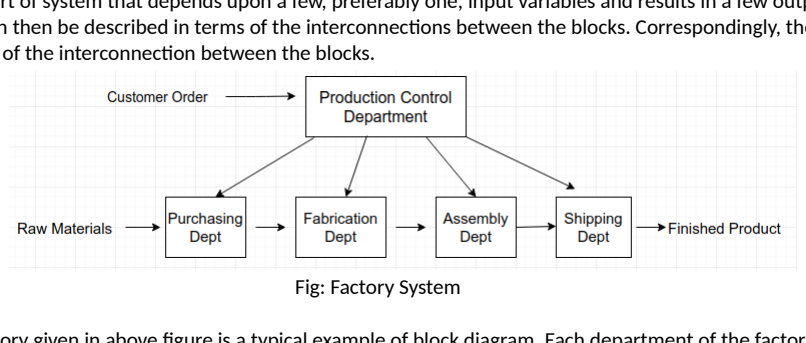


Fig: Factory System

The description of a factory given in above figure is a typical example of block diagram. Each department of the factory has been treated as a separate block, with the inputs and outputs being the work passed from department to department. The fact that the departments might occupy the same floor space and might use the same personnel or the same machines has been ignored.

ii. **Relevance**
→ The model should only include those aspect of the system that are relevant to the study objective. As an example, if the factory system study aims to compare the effects of different operating rules on efficiency, it isn't relevant to consider the hiring of employee as an activity. While irrelevant information in the model may not do any harm, it should be excluded because it increases the complexity of the model and causes more work in solving the model.

iii. **Accuracy**
→ The accuracy of the information gathered for the model should be considered. In the aircraft system, for example, the accuracy with which the movement of the aircraft is described depends upon the representation of the air-frame. It may suffice to regard the air-frame as a rigid body and derive a very simple relationship between control surface movement and aircraft heading, or it may be necessary to recognize the flexibility of the air-frame and make allowance for vibrations in the structure. An engineer responsible for estimating the fuel consumption may be satisfied with the simple representation. Another engineer, responsible for considering the comfort of the passengers, needs to consider vibrations and will want the detailed description of the air-frame.

iv. **Aggregation**
→ A further factor to be considered is the extent to which the number of individual entities can be grouped together into larger entities. The general manager of the factory may be satisfied with the description that has been given. The production control manager, however, will want to consider the shops of the departments as individual entities.

In some studies, it may be necessary to construct artificial entities through the process of aggregation. For example, an economic or social study will usually treat a population as a number of social classes and conduct a study as though each social class were a distinct entity.

Similar considerations of aggregation should be given to the representation activities. For example, in studying a missile defense system, it may not be necessary to include the details of computing a missile trajectory for each firing. It may be sufficient to represent the outcome of many firings by a probability function.

---

1 b) What is the name of computation of Monte Carlo method? Find the value I using the Monte Carlo method: $I = \int_2^5 2x dx$

Solution:

Standard value = $2\int_2^5 x dx$ = $2 [x^2/2]_2^5$ = 2 [25 – 4] = 21..............?

According to Monte Carlo Method,

b = 5
a = 2

To find c, for maximum value of f(x) or y:

f'(x) = 0
d/dx (2x) = 0

... (to be continued)

---

2 a) Discuss about continuous system simulation language (CSSL). Explain different component of analog methods.
==>

Analog method of system simulation is the use of Analog computer and other Analog Device in the simulation of continous system.

Different component of analog methods:

---

2 b) Explain Representation of Time in Discrete system simulation. Describe Significant event simulation.

Significant Event Simulation

Significant event simulation is a method of simulation organization that compares with an old one called the clock pulse method. It is used as an example for **automobile traffic models**. The significant event method is found to be more efficient than the clock pulse method at **low levels** of system interaction and less efficient at **high levels**.

- Another approach to represent the passage of time is called **significant event simulation.**
- This method is applicable to continuous system in which there are quiescent periods. The interval between the events in an event oriented approach is a quiescent period.
- This approach assumes that simple analytical function can be used to protect the span of a quiescent period.
- The significant event is one with the least span.
- Determining this event by simple comparisons of the projections allows the clock to be updated by an extended period of time.

[Bard]

Significant event simulation is a specific technique used within discrete event simulation. It focuses on optimizing the simulation by only considering events that significantly affect the system's state. This is particularly useful for systems with numerous minor events that don't significantly alter the overall behavior.

By focusing on significant events, this technique can significantly reduce the computational effort required for the simulation without sacrificing accuracy. Significant event simulation can further optimize the process by considering only impactful events, making it particularly useful for complex systems with frequent minor events.

3 a) What is lost call? How can we maintain the calls from being lost? Simulate the telephone system for such calls (Delayed calls).

---

3 b) Enlist the 6 common statistics use to generate the simulated output and explain how you measure them.

// Answer need to be conformed //
Six commonly required statistics which are usually included in the output of a simulation are as follows:

i. Counts	- giving the number of entities of a particular type or the number of times some event occurred.
ii. Summary measures	- such as extreme values, mean values, and standard deviations.
iii. Utilization	- defined as the fraction (or percentage) of time some entity is engaged.
iv. Occupancy	- defined as the fraction (or percentage) of time a group of entities in use on the average.
v. Distributions	- of important variables, such as queue lengths or waiting times.
vi. Transit times	- defined as the time taken for an entity to move from one part of the system to some other part.

[**chatGPT**]

Mean:
The average of all the values in a dataset. It is calculated by adding up all the values and dividing by the number of values. In simulation, the mean can be used to represent the expected value of the output.

Variance:
A measure of how spread out a dataset is. It is calculated by taking the sum of the squared differences between each value and the mean, divided by the number of values minus one. In simulation, the variance can be used to represent the degree of variability in the output.

Standard deviation:
The square root of the variance. It is a measure of the amount of variation or dispersion of a set of values from the mean. In simulation, the standard deviation is often used as a measure of how much the simulated output deviates from the expected value.

Maximum and minimum values:
The highest and lowest values in a dataset, respectively. They provide information about the range of values that the output can take.

Percentiles:
The values that divide a dataset into 100 equal parts. The nth percentile is the value below which n percent of the observations fall. In simulation, percentiles can be used to represent the range of values that the output can take, as well as to identify extreme values.

Confidence intervals:
A range of values that is likely to contain the true value of a population parameter with a certain degree of confidence. In simulation, confidence intervals can be used to estimate the range of values that the output can take with a certain degree of confidence.

---

4 a) How initial bias can be removed? Explain about replication of run in analysis of simulation output. *(ans from Vendanthakur website)*

Ans:

Replication of run in analysis of simulation output

Replication is essential for reducing sampling error and increasing the precision of estimates in simulation studies.

- Conduct Multiple Independenent Runs
- Collect Data from each runs
- Combine Results
- Analyze and Interpret
- Present Results

---

4 b) ~~Explain different statements in CSMP III.~~ Describe the Execution cycle for the simscript program with necessary diagrams.

---

5 a) "A random variable is drawn from an infinite population that has a stationary probability distribution with a finite mean and finite variance", elaborate this by using central limit theorem for estimation.

---

5 b) Workers come to a supply store at a rate of one every 5 ⁺₋2 minutes. Their requisition are processed by one of two clerks who takes 8-+4 minutes for each requisition. The requisition are then passed to a single storekeeper who fills them one at a time, taking 4+-3 minutes for each request. Draw the GPSS block diagram to simulate the queue of workers and measure the distribution of time taken for 1000 requisitions to be filled.

OR

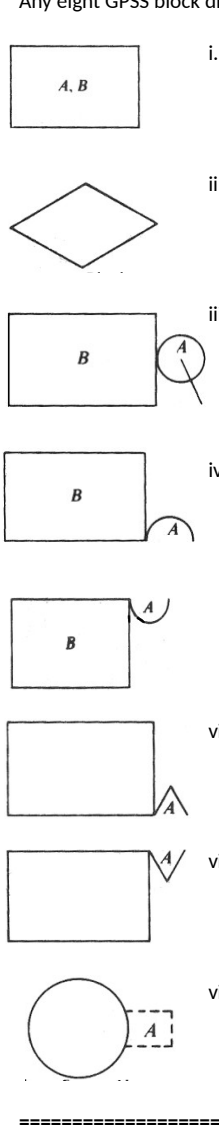
Explain SIMSCRIPT program execution cycle with necessary diagrams.

---

6 a) What is GPSS? Explain any eight GPSS block diagram symbols with their example.
~

GPSS is a language to simulate discrete systems to see how they perform over time.

Any eight GPSS block diagram symbols are enlisted down below:



i. Advance Block
==> It delays the progress of a Transaction for a specified amount of simulated time.
==> command: **ADVANCE A,B**
where, A = time increment.
B = time haft-range, or if a function, the function modifier.

ii. Transfer Block
==> It causes the Active Transaction to jump to a new Block location.
==> command: **TRANSFER A,B**
where, A = Transfer Block mode
B = Block number or location

iii. Depart Block
==> registers statistics which indicate a reduction in the content of a Queue Entity.
==> command: **DEPART A,B**
where, A = Queue Entity name or number
B = Number of units by which to decrease content of the Queue

iv. Enter Block
→ When a Transaction attempts to enter an ENTER Block, it either takes or waits for a specified number of storage units.
→ command: **ENTER A,B**
where, A = Storage Entity or Number
B = No of units by which to decrease the available storage capacity.

v. Leave Block
==> It increases the accessible storage units at a Storage Entity.
==> command: **LEAVE A,B**
where, A = Storage Entity name or number
B = Number of storage units

vi. Seize Block
→ It creates transaction for the future entry into the simulation.
→ command: **SEIZE A**
where, A = Facility name or number.

vii. Release Block
→ It releases ownership of a Facility, or removes a preempted Transaction from contention for a Facility.
→ command: **RELEASE A**
where, A = Facility Number

viii. Terminate
→ It removes the Active Transaction from the simulation and optionally reduces the Termination Count.
→ command: **TERMINATE A**
where, A = Termination Count Decrement

---

6 b) What are advantages of simulation language over the general purpose programming language for simulation study? Explain about temporary and permanent entities in simscript.

---

7. Write short notes on:

a) Types of Models

---

b) Measuring utilization and occupancy

A common requirement of simulation is measuring the load on some entity, such as an item of equipment. The simplest measure is to determine what fraction of time the item was engaged during the simulation run. The term utilization will be used to describe this statistic.

For Utilization statistics, timing information must be kept for each individual entity. Occupancy statistics only require keeping a count of a class of entities, and recording the last time the count changed, just two numbers. If the number of active entities is large, it can cost a great deal more space and time to record utilization than occupancy.

---

c) ~~Hybrid simulation~~

Fall 2017

1 a) Define simulation and explain the importance of simulation contrasting its application.

---

1 b) What is Monte Carlo Method and why it is used? Explain steps for the calculation and give a suitable example of Monte Carlo method.
~

Monte Carlo Simulation refers to the type of simulation in which a static, approximate, and stochastic model is used for a deterministic system.

---

2 a) Draw the Cobweb model of a market economy for the following condition:

D = 12.4 – 1.2 P
S = 1.0 + 0.9 P_{-1}
P_0 = 1.0

Ans:

Given:
D = 12.4 –1.2P
S = 1.0 + 0.9P_{-1}
P_0 = 1.0

Now, in equilibrium condition, we know: Demand (D) = Supply (S)
∴ 12.4 – 1.2P = 1.0 + 0.9P_{-1}
12.4 – 1 = 0.9P_{-1} + 1.2P
11.4 = 0.9P_{-1} + 1.2 P

... (to be continued)

OR

Explain Event and Interval Oriented Time Advance Mechanism with suitable example of each.

---

2 b) Define CSMP III and explain the types of statements.
==>

CSMP III, or Continuous System Modeling Program III is an early scientific computer software designed for modeling and solving differential equations numerically. This enables real-world systems to be simulated and tested with a computer.

The types of statements are:

i) Structural Statements are those statement which define the model. They consist of FORTRAN-like statement and functional blocks designed for operations that frequently occurs in a model definition. Structural statements can make use of the operations of addition, subtraction, multiplication, division, and exponentiation, using the same notation and syntax rules as are used in FORTRAN.

If the model include the equation $X = (6Y/W) + (Z-2)^2$. Then the following statement would be used:

```
X = 6.0*Y/W+(Z-2)**2.0
```

ii) Data Statements are those statement which assign numerical values to various changing parameters, constants, and initial conditions. For example, one data statement called INCON can be used to set the initial value of integration function block.

iii) Control Statements, which specify options in assembly and execution of the program, and the choice of output of the results of the calculations performed. For e.g. if printed output is required, control statements with PRINT and PRDEL are used followed by the names of variables to form the output.

---

3 a) ~~What is Feedback system?~~ Explain parasite-host model with suitable example of each.

---

3 b) Define Discrete event simulation. Explain simulation of a telephone system.
~

Discrete event simulation (DES) is the process of codifying the behavior of a complex system as an ordered sequence of well-defined events. In this context, an event comprises a specific change in the system's state at a specific point in time.

→ The system is described by a **state**.
→ The state changes only at discrete points in time, called **events**.
→ The interval between events is called a **delay**, or **duration**. The delay could be random.
→ Events can trigger other events depending on conditions that depend on the state.

To model a telephone system we consider the following entities:
→ Telephone Lines
→ Links (through which call can be established),
→ Phone Calls.

Temporary entities are those that are created and destroyed during the simulation whereas permanent entities remain during the run. Usually entities declared as permanent are stored collectively rather than in individually identifiable records. Unlike temporary entities, permanent entities are not destroyed individually; they are destroyed collectively. In this respect telephone lines and links should be permanent entities because they are usually permanent and can be handled collectively. But individual phone call created for a short period of time and after that they should be destroyed. So we can consider phone call as temporary entity.

---

4 a) What is Bootstrapping and why it used? Explain the Generation of Arrival Patterns in discrete system simulation.
~

Bootstrapping is a statistical procedure that re-samples a single data-set to create many simulated samples.

It is used to calculate standard errors, construct confidence intervals, and perform hypothesis testing for numerous types of sample statistics.

Generation of Arrival Patterns

Trace driven simulation:
- Here the sequence of inputs are generated from observations of a running system.
- Programs monitors are attached to the running system to extract the data with little or no disturbances of the system operation.

Bootstrapping:

Here the arrival time of the next entity is immediately calculated from the inter-arrival time distribution.

The term bootstrapping is used to describe this process of making one entity create its successor.

The method requires keeping only the arrival time of the next entity.

It is the most preferred method of generating arrival through computer simulation program.

---

4 b) Explain Kolmogorov-Smirnov test and write* down* the* steps carried out for the test.

The Kolmogorov-Smirnov Test (K-S Test) is a nonparametric test used to compare a sample distribution to a reference probability distribution. The K-S Test evaluates whether two samples are drawn from the same distribution by comparing their cumulative distribution functions.

The steps for carrying out the Kolmogorov-Smirnov Test are:

➔ Calculate the cumulative distribution functions (CDFs) of the two samples.
➔ Calculate the maximum absolute difference (D) between the two CDFs.
➔ Calculate the critical value, Dc, for the given significance level (alpha).
➔ If D > Dc, then the two samples are not from the same population.
➔ If D < Dc, then the two samples are likely to be from the same population.

\# Test
1. Testing for uniformity
- Kolmogorov Smirnov
- Chi-Square test
2. Testing for randomness
- Autocorrelation Test
- Run Test

Or

Using the multiplicative congruential method, find the period of the generator and set of random numbers for a=13, $m=2^6$ and X_0=1 and 2.

==>

---

5 a) Discuss briefly about GPSS. Draw the blocks used in GPSS and also write about any five basic commands.
~

GPSS (General Purpose Simulations System) language was developed principally by the IBM Corporation published in 1961. The system which is to be simulated in GPSS is described by a block diagram in which the blocks represent the activities, and lines joining the blocks indicate the sequence in which the activities can be executed. Where there is a choice of activities, more than one line leaves a block and the condition for the choice is stated the block.

Any five basic commands for GPSS are:

1. START	→ Set the Termination Count and begin a simulation.
2. RESET	→ Reset the statistics of the simulation.
3. CONTINUE	→ Resume the simulation.
4. HALT	→ Stop simulation and delete all Queued Commands.
5. STOP	→ Set a Stop Condition based on Block entry attempts.

GPSS – Basic commands

CLEAR	reset statistics and remove transaction
CONTINUE	resume the simulation
EXIT	end the GPSS world session
HALT	stop the simulation and delete all queued commands
INCLUDE	read and translate a secondary model file
INTEGRATE	automatically integrate a time differential in a use variable
REPORT	set the name of the report file or request an immediate report
RESET	reset the statistics of the simulation
SHOW	evaluate and display expression
START	set the termination count and begin a simulation
STEP	attempt a limited number of block entities
STOP	set a stop condition based on block entry attempts
STORAGE	define a storage entity
TABLE	define a table entity
VARIABLE	define a variable entity

---

5 b) Explain the SIMSCRIPT execution life cycle.
~

SIMSCRIPT is an event-statement oriented discrete language. A completely new version SIMSCRIPT II was released by the RAND Corporation in 1968.

About SIMSCRIPT
1. User should know programming in FROTRAN or ALGOL for learning SIMSCRIPT.
2. It is capable of representing more complex data structures and can execute more complex design rule.
3. It is able to produce a more compact model that requires less storage space and generally will be executed more rapidly.
4. SIMSCRIPT program can be implemented on several different manufactures' computer system and can be applied in general programming problems.

Features of SIMSCRIPT
(1) Machine-independent general-purpose simulation language.
(2) Algorithmic capabilities comparable to those of ALGOL or PL/1.
(3) Simulation concepts are relatively few and very general.
(4) Data collection facilities are excellent.
(5) Input-output facilities are good.
(6) Flexibility for experimental design is good.
(7) Machine efficiency is high.
(8) Harder to learn than GPSS.

Organization of a SIMSCRIPT Program:
Event routines are closed routines and some means must be provided for transferring control between them.
The transfer is affected by the use of event notices which are created when it is determined that an event is scheduled. If the event is to involve one of the temporary entities, of which these maybe many copies, the event notice will usually identify which one is involved.

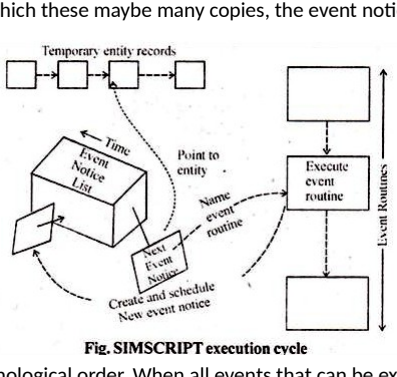


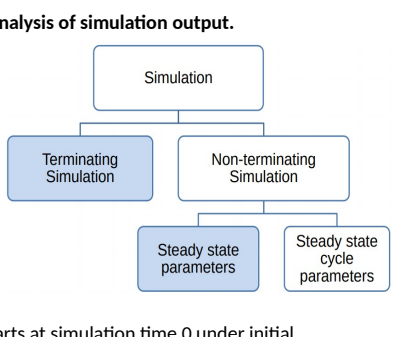
Fig. SIMSCRIPT execution cycle

The event notices are filled in chronological order. When all events that can be executed at a particular time have been processed, the clock is updated to the time to the next event notice and control is passed to the event routine identified by the notice. These actions are automatic and do not need to be programmed.

---

6 a) Explain the types of simulation on the basis of output. Define and explain estimation methods used in analysis of simulation output.
~

There are two types of simulation on the basis of output analysis:



i) **A terminating simulation** is one that runs for some duration of time T_E, where E is a specified event or set of events which stops the simulation. Such simulation starts at time 0 under specified initial conditions and stop at the stopping time T_E. It is also known as **Finite-Horizon Simulation**.
➔The different runs use independent random numbers and same initialization rule.
➔The event E often occurs at a point when the system is cleaned out.
➔ Initial condition for a terminating simulation generally affect the desired measure of performance, these conditions should be representative of those actual system.

ii) **Non-Terminating Simulation** is a system that runs continuously, or at least for a very long period of time. It starts at simulation time 0 under initial conditions defined by the analyst and runs for some analyst defined period of time T_E. It is also known as **Steady-State Simulation**.
A steady-state simulation is a simulation whose objective is to study long-run behavior of a non-terminating system.

After it focuses on the estimation of steady-state system parameters. The estimation techniques include the replication/deletion approach,the regenerative method, the batch means method, and the standardized time series method. Second, it reviews recent statistical procedures to find the best system among a set of competing alternatives.

---

6 b) Why estimation of initial bias is used in Simulation output? Explain.

~~Estimation of initial bias (bias means unevenness or imbalance) is used in simulation output to know what errors are causing the changes in given output. Initialization bias problem can lead to errors, particularly in steady-state output analysis.~~

~~How should the simulation be initialized? Suppose that a machine shop closes at a certain time each day, even if there are jobs waiting to be served. You have to be careful to start each day with a demand that depends on the number of jobs remaining from the previous day.~~
~~Initialization bias can lead to point estimators for steady-state parameters having high mean squared error.~~
~~Since initialization bias raises important concerns, how do we detect and deal with it? In the end, the estimate can still has few % bias to the true expected value. The question becomes, how much bias is acceptable?~~

Dictionary:
Truncate: To shorten by cutting off

~~If initialization bias is detected, one may want to do something about it. Two simple methods for dealing with bias:~~

~~(a) Truncate the output by allowing the simulation to "warm up" before data are retained for analysis. Experimenter hopes that the remaining data are representative of the steady-state system. Output truncation is probably the most popular method for dealing with initialization bias; and all of the major simulation languages have built-in truncation functions.~~

~~(b) Make a very long run to overwhelm the initialization effects. This method of bias control is conceptually simple to carry out and may yield point estimators having lower mean squared errors than the analogous estimators from truncated data. However, a problem with this approach is that it can be wasteful with observations; for some systems, an excessive run length might be required before the initialization effects are rendered negligible.~~

---

7) Write Short on:

a) Verification and Validation of model:

Verification is the process of determining whether the simulated computer program works as intended or not. It ensure that product is being build according to specified requirement and design. It ask question like "Are we building the model right?". It is carried out by QA (Question & Answer) teams to check whether the implementation of the model is as per specification document or not. It is carried out before the validation. Reviews, meetings and inspections are involved in this process. Verification process explains whether the outputs are according to inputs or not.

Validation is the process of determining whether the conceptual model is an actual representation of actual system being analyzed. It ask question like," Are we building right model?". It is process of evaluating model at the end of the development process to determine whether

model meets the expected requirements. Validation is carried out just after the verification. Black box testing, White box testing, etc are involved in this process. Validation process describe whether the model is accepted or not.

The verification and validation model is also called V-model.

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b) Pseudo Random numbers: A pseudo random numbers are the unique random numbers generated by *pseudo-random number generator* (PRNG) which is a computer program written for, and used in, probability and statistics applications when large quantities of random digits are needed. Most of these programs produce endless strings of single-digit numbers, usually in base 10, known as the decimal system. When large samples of pseudo-random numbers are taken, each of the 10 digits in the set {0,1,2,3,4,5,6,7,8,9} occurs with equal frequency, even though they are not evenly distributed in the sequence.

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c) Hybrid ~~Computers~~ Simulation: //Note: Hybrid Computer is not in our course. Hybrid Simulation is. May be printing mistake!

Hybrid simulation is a testing method for examining the seismic response of structures using a hybrid model comprised of both physical and numerical substructures. Because of the unique feature of the method to combine physical testing with numerical simulations, it provides an opportunity to investigate the seismic response of structures in an efficient and economically feasible manner. It is this feature of the method which made it gain widespread use in recent years. This paper presents the theory of the method including an overview of the previous research related to various aspects of the method, an overview of two hybrid simulation applications, and the future directions for transforming the method to its next generation.

2015 Spring

1 a) Define system modeling? What are the various types of system models? Explain each of them.

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1 b) What is Monte Carlo method? Briefly describe its historical background. ~~Find the value of π (pie) using Monte Carlo method.~~

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2 a) Explain the steps of Simulation study.

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Simulation study is carried out in various steps. There are 12 steps in simulation study:

i. **Problem formulation**

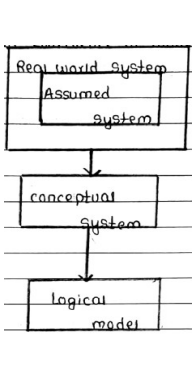
Every study begins with a statement of the problem, provided by policy makers. Analyst ensure it's clearly understood. If it is developed by analyst, policy makers and analysts are aware that there is problem long before the nature of the problem is known.

ii. **Setting of objectives and overall project plan**

The objectives indicate the questions to be answered by simulation. At this point a determination should be made concerning whether simulation is the appropriate methodology. Assuming its is appropriate, the overall project plan should include:

- ➔ A statement of alternative systems.
- ➔ A method for evaluating the effictiveness of these alternatives.
- ➔ Plans for the study in terms of the number of people involved.
- ➔ Cost of the study.
- ➔ Number of days required to accumplish each phase of the work with anticipated result.

iii. **Model conceptualization**



The construction of a model of a system is probably as much art as science. The art of ~~science~~ is enchanced by ability.

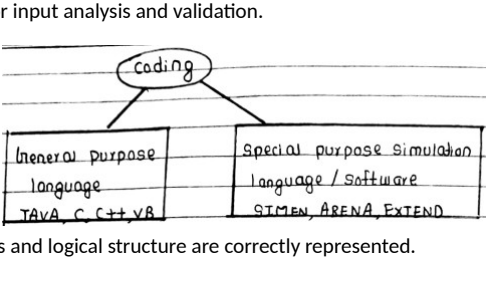
- ➔ To abstract the essential feature of problem.
- ➔ To select and modify basic assumptions that characterizes the system.
- ➔ To enrich and elaborate the model until a useful approximation system.

Thus, it is best to start with a simple model and build toward greater complexity. Model conceptualization enchances the quality of the resulting model and increase the confidence of model user in the application of the model.

iv. **Data collection**

There is a constant interplay between the construction of model and the collection of needed input data. It is done in early stages objectives kind of data are collected. The data collected are used for input analysis and validation.

v. **Model translation**



Real world system result in models that require a great deal of information storage and computation. It can be programmed by using simulation languages or special purpose simulation software. Simulation language are powerfull and flexible. Simulation software models development time can be reduced.

vi. **Verification**

It pretains to the computer and checking the performance. If the input parameters and logical structure are correctly represented. Verification is completed.

vii. **Validation**

It is determination that a model is an accurate representation of the real system. It is achieved through calibration of the model.

viii. **Experimental Design**

ix. **Production run and analysis**

x. **More runs**

xi. **Documentation and reporting**

i. Program documentation

ii. Process documentation

xii. **Implementation**

Sucess depends on the previous steps. If the model user has been thoroughly involved and understood the nature of model and its outputs, likelihood of a vigorous implementation is enchanced.

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2 b) What are the various component of Analog Computer? Draw the analog computer for the following function:

$$a\ddot{x} + bx - c\theta = F(t)$$

$$e\ddot{\theta} + f\theta - gx = G(t)$$

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3 a) Explain telephone system simulation with busy call.

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3 b) Define Linear & Non-Linear differential equation. ~~Explain CSMP III statement with example.~~

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4 a) Discuss the major task performed in simulation of programming.

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4 b) Why random numbers are useful? Test the following random numbers for their uniformity:

0.44 0.81 0.14 0.05 0.93

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5 a) Define GPSS. Explain different types of block along with their characteristics.

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5 b) Explain the organization of SIMSCRIPT program with necessary diagram.

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6 a) What is estimation method? Discuss the various methods of elimination of internal bias of simulation output.

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6 b) How replication of run can be used in simulation output?

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7) Write short notes on any two:

~~**a) Feedback**~~

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b) Queuing System

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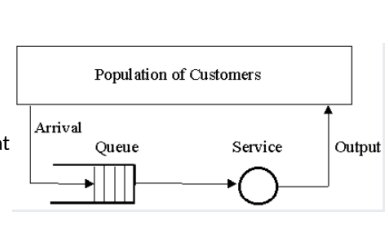

The combination of all entities in system being served and being waiting for service will be called as queueing system.

The key elements of queuing systems are customer and server. Customer refers to anything that arrives at a facility and requires service. E.g. people, machines, trucks, emails. Servers refers to any resource that provides the requested service. E.g. receptionist, teller, CPU, etc.

There are five characteristics of queuing system:

i. Calling population // is the population of potential customers those require service from system. It may be finite or infinite.

ii. Arrival Process // for infinite-population models is usually characterized in terms of inter-arrival times of successive customers.

iii. Service Process // can be measured by the number of customers served per some unit of time or the time taken to complete the service.

iv. Queuing Discipline/Behavior // refers to the rule that a server uses to choose the next customer from the queue when the server completes.

- LIFO - FIFO - SIRO - Priority

v. Number of Servers // Servers represent the entity that provides service to the customer. A system may consist of single server or multiple servers.

==

c) Cobweb models

2013 3a) Draw the analog computer for following function:

$a\ddot{x} + bx - c$

Extra Notes

What is the difference between simulation and modeling?

Modeling is the act of building a model. A simulation is the process of using a model to study the behavior and performance of an actual or theoretical system. In a simulation, models can be used to study existing or proposed characteristics of a system.

~~**Types of Simulation**~~

~~***Monte Carlo Simulation***~~ — *It is used in situation involving probability or chance where outcome is uncertain.*

~~***Operational Gaming***~~ — *It is about competition. It involve 2 or more competing players.*

~~***System Simulation***~~ — *It is about simulation of very large system.*

Monte Carlo Numerical

Question:

Number of cases of Cars coming per hour in Car-Wash during past 200 hours is given:

No of cars arrivals	Frequency
4	20
5	30
6	50
7	60
8	40

Requirements:

i) Setup the probability and cumulative probability distribution for the variable of car arrivals.
ii) Establish random number of interval for variable.
iii) Simulate 15 hrs of car arrivals & compute average number of arrivals per hrs.

Solution:

Using above data, we can calculate:

No. of cars arrivals	Frequency	Probability	Cumulative Probability	Random No. of Interval
4	20	0.10	0.10	1 - 10
5	30	0.15	0.25	11 - 25
6	50	0.25	0.50	26 - 50
7	60	0.30	0.80	51 - 80
8	40	0.20	1.00	81 - 00
Total	200	1.00		

where,

Probability = Frequency / Total Frequency

Cumulative Probability = Previous Cumulative Probability + Current Probability //this is not a standard way to write the formula

Random No. of Interval is calculated with Cumulative Probability; which always starts with 1 and ends with 0. Its a convention we need to follow.

Now, to solve 3rd requirement of the question:

We can write any random numbers which comes in our mind. And put it in **Random Numbers** column.
We need to write **Cars arrivals** of 15 hrs starting from 1 hrs to 15 hrs.
We can calculate **Simulate no. of arrivals** by using current **Random Numbers** value and its corresponding **No. of Cars arrivals** from previous calculated table.

Car arrivals (hrs)	Random Numbers	Simulated no. of arrivals
1	28	6
2	36	6
3	66	7
4	78	7
5	11	5
6	29	6
7	40	6
8	55	7
9	88	8
10	91	8
11	5	4
12	17	5
13	38	6
14	60	7
15	99	8
Total		96

Note: The answer is different depending of what **Random Numbers** students have chooses.

Therefore,

Average no. of arrivals per hours = 96 / 15 = 6.4 cars. // Cars can't be in be decimal in real world. So, write 6 if you want.