IE 324 - Simulation
Fall 2017
Study Set 3

1. Consider a **G/G/2** queuing system in which customers take service from Server 1 when both servers are available.

Inter-arrival times : 0.6, 0.2, 0.1, 0.3, 0.6, 0.1, 0.3, 0.2, 0.4, 0.2, 0.3, 0.8, 0.4
Service times of Server 1 : 0.4, 0.7, 0.3, 0.3, 0.7, 0.1, 0.4, 0.3, 0.5, 0.1, 0.8, 0.4, 0.2
Service times of Server 2 : 0.6, 0.4, 0.6, 0.4, 0.8, 0.3, 0.5, 0.5, 0.3, 0.5, 0.7, 0.2, 0.5

Using the inter-arrival and service times given above (in minutes) in the given order, create a record of hand simulation using the event-scheduling algorithm until time *TE = 4* minutes and compute the below stated performance measures. Assume that the first arrival occurs at time *t = 0*.

- **a.** Average number of jobs in the system
- **b.** Average number of jobs in the queue
- **c.** Utilization of Server 1
- **d.** Utilization of Server 2
- **e.** Average time in the system
- **f.** Average waiting time in the queue
- **g.** Maximum number of jobs in the queue
- **h.** Maximum waiting time in the queue
- **i.** Total number of jobs that arrived at the system
- **j.** Total number of jobs that started service
- **k.** Total number of jobs completed service

2. Consider a **G/G/2 FIFO** queuing system in which customers take service from Server 1 when both servers are available. At $t = 2.5$, Server 1 leaves permanently and all customers start to take service from Server 2. If Server 1 is already serving a customer at $t = 2.5$, then Server 1 leaves immediately after the customer departs. The queuing rule changes to **LIFO** at $t = 2.5$ and remains as **LIFO** until the termination time. If there is an entity that leaves the queue at $t = 2.5$, the queuing rule changes immediately after the entity leaves.

Inter-arrival times: 0.2, 0.5, 0.1, 0.4, 0.2, 0.1, 0.2, 0.1, 0.6, 0.5, 0.2, 0.4, 0.2, 0.4, 0.6
Service times of Server 1: 0.3, 0.1, 0.1, 0.7, 0.6, 0.1, 0.4, 0.7, 0.5, 0.4, 0.8, 0.3, 0.3
Service times of Server 2: 0.3, 0.7, 0.5, 0.4, 0.8, 0.2, 0.5, 0.4, 0.6, 0.5, 0.7

Using the inter-arrival and service times given above (in minutes) in the given order, create a record of hand simulation using the event-scheduling algorithm until time *TE = 4* minutes and compute the below stated performance measures. Assume that the first arrival occurs at time *t = 0*.

When using the service times, consider the rule given in the following example: If Entity 2 is the first entity that enters Server 2, it should use the **first** time given for Server 2, not the **second** time.

- **a.** Average number of jobs in the system
- **b.** Average number of jobs in the queue
- **c.** Utilization of Server 1
- **d.** Utilization of Server 2

- **e.** Average time in the system
- **f.** Average waiting time in the queue
- **g.** Maximum number of jobs in the queue
- **h.** Maximum waiting time in the queue
- **i.** Total number of jobs that arrived at the system
- **j.** Total number of jobs that started service
- **k.** Total number of jobs completed service

3. Approximate the integral

$$\int_{2}^{11}\left(\sqrt{2x}+\frac{x}{x^2-1}\right)dx$$

Write a MATLAB code that calculates the approximate value of θ, by performing 5,000 replications.

4. Approximate the integral

$$\int_{3}^{8}\left(x^2-\sqrt[4]{4x}-e^{-x}\right)dx$$

Write a Matlab code that calculates the approximate value of θ, by performing 2,000 replications.

5. Approximate the integral

$$\int_{-\infty}^{\infty} e^{-x^2}dx$$

Write a Matlab code that calculates the approximate value of θ, by performing 2,000 replications.

6. A simulation model of a job shop was developed to investigate different scheduling rules. To validate this model, the scheduling rule currently used was incorporated into the model and the resulting output was compared against observed system behavior. By searching the previous year's database records, it was estimated that the average number of jobs in the shop was 22.5 on a given day. Seven independent replications of the model were run, each of 30 days' duration, with the following results for average number of jobs in the shop:

18.9	22.0	19.4	22.1	19.8	21.9	20.2

Develop and conduct a statistical test to evaluate whether model output is consistent with system behavior. Use the level of significance α = 0.05.

7. System data for the job shop of Exercise 4 revealed that the average time spent by a job in the shop was approximately 4 working days. The model made the following predictions, on seven independent replications, for average time spent in the shop:

3.70	4.21	4.35	4.13	3.83	4.32	4.05

Is model output consistent with system behavior? Conduct a statistical test, using the level of significance α = 0.01.

8. For the job shop of Exercise 4, four sets of input data were collected over four different 10-day periods, together with the average number of jobs in the shop Z_i for each period. The input data were used to drive the simulation model for four runs of 10 days each, and model predictions of average number of jobs in the shop Y_i were collected, with these results:

i	1	2	3	4
Z_i	21.7	19.2	22.8	19.4
Y_i	24.6	21.1	19.7	24.9

Conduct a statistical test to check the consistency of the system output and model output. Use the level of significance $\alpha = 0.05$.