

1. Consider a queueing system during a time period  $(0, 10)$ . Initially the system is empty,  $L_0 = 0$ . New customers enter the queue at times  $a_i$  and depart at times  $d_i$ .

$a_i$	1.5	2.0	3.5	6.5	7.5	8.0	9.5
$d_i$	4.0	5.0	5.5	7.0	-	-	-

Compute the average number of customers in the system during the time period  $(0, 10)$ . Apply, the ideas on slide 13 in Statistical analysis, part 1.

2. Assume that initially there are three customers in the system  $L_0 = 3$ . How does that affect the computation of the mean number of customers above?
3. In seven independent simulation replications of a system it has been observed that the average waiting time of the customers arriving during a 2 hour interval has been (3.62, 4.55, 3.95, 3.71, 4.12, 4.61, 3.24) min. The expectation of this average waiting time has to be estimated such that the error is 0.3 min at 90 % confidence level. Assume that all the seven samples obey the Normal distribution. How many independent replications are needed to achieve the desired accuracy? Hint: use the Student-t distribution.
4. Write a simulation script (with your favorite tool) to generate samples of  $X \in (0, 1)$  obeying the beta distribution  $\beta(2, 4)$  with the pdf

$$f(x) = 20x(1 - x)^3, \quad 0 \leq x \leq 1.$$

To estimate the mean value of  $X$ ,  $E[X]$ , generate 10000 samples and give the 95% confidence interval. Hint: for sample generation see slide 4 in Generation of random numbers, part 2. Also, remember that all samples of  $X$  are independent.

5. We can estimate the value of the constant  $e$  by the following algorithm. Generate samples of  $N$  according to

$$N = \min \left\{ n : \sum_{i=1}^n U_i > 1 \right\},$$

where  $U_i$  are independent and  $U_i \sim U(0, 1)$ , i.e., one generates random numbers until their sum exceed 1 and one records the number of trials required for that. Then it can be shown that  $E[N] = e$ . Implement the above algorithm (with your own favorite tool). Generate 10000 samples to estimate  $e$  and give its 95% confidence interval. Hint: remember that all samples of  $N$  generated with above algorithm are independent.