Applied Mathematics 3911
Winter 2020
Assignment # 4

Due: Tuesday March 24, 2020 (by 5pm, in the my office. Rm 285 MSC)

Assignment 4 Simulation of a Bank Teller

Part 1:

As an example of the concept of discrete event simulation, **write a program to simulate the processing of customers by a teller at a bank**. Customers arrive at the bank, wait for service by the teller if the teller is busy, are served, and then depart the system. Customers arriving to the system when the teller is busy wait in a single queue in front of the teller. For simplicity, initially assume that the time of arrival of a customer and the service time by the teller for each customer are known and are shown below. The objective is to manually simulate the above system to determine the percent of time the teller is idle and the average time an average customer spends at the bank.

Customer #	Time of Arrival (Minutes)	Service Time (Minutes)
1	3.2	3.8
2	10.9	3.5
3	13.2	4.2
4	14.8	3.1
5	17.7	2.4
6	19.8	4.3
7	21.5	2.7
8	26.3	2.1
9	32.1	2.5
10	36.6	3.4
11	40.3	2.0
12	41.9	5.0
13	43.9	3.0

Hints/Background:

Since the simulation is the dynamic portrayal of the changes in the state of a system over time, the states of the system must be defined. For this example, they can be defined by the status of the teller (busy or idle) and by the number of customers at the bank. The state of the system is changed by a customer arriving to the bank, and the completion of service by the teller and subsequent departure of the customer. In the simulation, one determines the state of the system over time by processing the events corresponding to the arrival and departure of customers in a time-ordered sequence. So in this simulation time does not flow in uniform steps, but changes according to the next event to occur. The results of your simulation for this example should corresponded to the values in the table below. It is assumed that initially there are no customers in the system, the teller is idle, and the first customer is to arrive at time 3.2. (So the simulation really starts at t=0 but until t=3.2 the teller is idle and no customers are waiting.) The last three rows are only partially filed so I can check your code. This first 10 rows are complete so **you** can check your code.

Customer Number (1)	Arrival Time (2)	Start Service Time (3)	Departure Time (4)	Time in Queue (5)=(3)-(2)	Time in Bank (6)=(4)-(2)
1	3.2	3.2	7.0	0.0	3.8
2	10.9	10.9	14.4	0.0	3.5
3	13.2	14.4	18.6	1.2	5.4
4	14.8	18.6	21.7	3.8	6.9
5	17.7	21.7	24.1	4.0	6.4
6	19.8	24.1	28.4	4.3	8.6
7	21.5	28.4	31.1	6.9	9.6
8	26.3	31.1	33.2	4.8	6.9
9	32.1	33.2	35.7	1.1	3.6
10	36.6	36.6	40.0	0.0	3.4
11	40.0				
12	41.0				
13	41.3				

In the above table, columns (1) and (2) are taken from the first table. The start of service time given in column (3) depends on whether the preceding customer has departed the bank. It is taken as the larger value of the arrival time of the customer and the departure time of the previous customer. Column (4), the departure time, is the sum of the column (3) value and the service time for the customer given in the first table. Values for time in queue and time in bank for each customer are computed as shown in the above table. Average values per customer for these variables are 2.61 minutes and 5.81 minutes, respectively. Your code should calculate columns 3-6. and the averages.

The logic associated with processing the arrival and departure events depends on the state of the system at the time of the event. In the case of the arrival event, the disposition of the arriving customer is based on the status of the teller. If the teller is idle, the status of the teller is changed to busy and the departure event is scheduled for the customer by adding his service time to the current time. However, if the teller is busy at the time of an arrival, the customer cannot begin service at the current time and, therefore, he enters the queue (the queue length is increased by one). For the departure event, the logic associated with processing the event is based on queue length. If a customer is waiting in the queue, the teller status remains busy, the queue length is reduced by one, and the departure event for the first waiting customer is scheduled. However, if the queue is empty, the status of the teller is set to idle. Before writing any computer code you should document this logic in a flow chart!

To place the arrival and departure events in their proper chronological order, it is necessary to maintain a record calendar of future events to be processed. This is done by maintaining the times of the next arrival event and the next departure event. The next event to be processed is then selected by comparing these event times. For situations with many events, an ordered list of events would be maintained which is referred to as an event file or event calendar. There are several important concepts illustrated by the above example. We observe that at any instant in simulated time, the model is in a particular state. As events occur, the state of the model may change as prescribed by the logical-mathematical relationships associated with the events. Thus, the events define the dynamic structure of the model. Given the starting state, the logic for processing each event, and a method for specifying sample values, our problem is largely one of bookkeeping. An essential element in our bookkeeping scheme is an event calendar which provides a mechanism for recording and sequencing future events. Another point is that we can view the state changes from two perspectives: the process that the customer encounters as he seeks service (the customer's view), or the events that caused the state of the teller to change (the teller's or bank's view).

Part 2:

Alter your code so that there is more than a single teller; try 2 at first or perhaps let the number of tellers be a variable you can set. Create a table of your own with Customer arrival time and required service time. Then use your simulation to create a table as above that tracks the percent of time each teller is idle and the average time an average customer spends at the bank. Assume when a customer arrives they choose the shortest line, each teller has a line, and that they can not change lines. Discuss the difference in your results for a single teller and more than one teller. State any additional assumptions you make.

If you are the owner of the bank discuss how you might use this data as an optimization tool; limit this discussion to 2 or 3 sentences at most.