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Single Server Queue SImulation

Programming Language: Python
IDE: spyder
Libraries: random,numpy and sys

The program allows one to choose between gaussian(1) or IID(2).
Generates a random number of rows every time it is run.

Gaussian Distribution:
Here we generate inter-arrival time and service time.
Takes input of mean and standard deviation.
NumPy function which returns an array/list. It generates gaussian distribution.
array=np.random.normal(mean,sd,rows)
This array will contain negative values so to deal with them we shifted the negative values. The minimum value in the array is subtracted from every array element.
array=array-min(array)
Both inter-arrival time and service time are calculated this way.

IID Distribution:
Here we generate inter-arrival time and service time.
Takes input of max delay that can occur between the arrival of two customers for IAT and max service time.
We use the random library function uniform. It returns a single value so we run it in a loop making each element independent of others as they are separately generated unlike in gaussian.
Iat = rn.uniform(0,delay_cust)
Service Time = rn.uniform(0,max_service_time)
This function takes lower and higher limits. For the higher limit we set it as the max delay that can occur between the arrival of two customers for IAT and max service time for service time.

Calculating Other Columns:
Arrival time calculated using the inter-arrival time. We add the current IAT to the arrival time of the previous customer.
Start serving time is the leave time for the previous customer.
Exit time is the start of service plus the total service time.
Delay/wait is the difference between arrival time and start of service time.
To find queue length I have used binary search count. It is calculated when a customer is served.

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Observation:

For IID if we keep max serve time<max delay between customers, we start getting queue length 0 more frequently. This is because customers arrive after a customer has been served. Waiting time decreases.

For IID if we keep max serve time>max delay between customers, the queue starts building up. This implies that the serving rate is slower than the customer arrival rate.

For Gaussian if we keep mean<SD, the inter-arrival time increases along with the serving time. This meant that none had to wait.

To get a reasonable system we need to keep the SD< mean. The SD should be very less than mean.

Gaussian Outputs:

```
Python 3.7.6 (default, Jan  8 2020, 20:23:39) [MSC v.1916 64 bit (AMD64)]
Type "copyright", "credits" or "license" for more information.

IPython 7.12.0 -- An enhanced Interactive Python.

In [1]:          'C:/Users/mujta/smsTest/Single_Server_Queue.py'       ='C:/Users/
mujta/smsTest'
Enter 1 for gaussian 2 for IID:

1
gaussian
Enter Mean:

23
Enter SD:

45
```

ID	IAT	Arr	Delay	Start	Serve	Exit	Queue
1	110.7	110.7	0.0	110.7	120.9	231.6	0
2	178.1	288.8	0	231.6	36.1	267.7	0
3	63.1	351.9	0	267.7	99.8	367.5	0
4	166.7	518.6	0	367.5	182.5	550.0	0
5	190.2	708.8	0	550.0	148.5	698.5	0
6	65.0	773.8	0	698.5	125.3	823.8	0
7	104.6	878.4	0	823.8	69.6	893.4	0
8	105.2	983.6	0	893.4	71.7	965.1	0
9	84.0	1067.6	0	965.1	114.1	1079.2	0
10	87.8	1155.4	0	1079.2	132.6	1211.8	0
11	184.6	1340.0	0	1211.8	110.4	1322.2	0
12	68.3	1408.3	0	1322.2	77.8	1400.0	0
13	110.6	1518.9	0	1400.0	92.0	1492.0	0
14	96.8	1615.7	0	1492.0	21.0	1513.0	0
15	163.0	1778.7	0	1513.0	54.3	1567.3	0
16	225.5	2004.2	0	1567.3	138.3	1705.6	0
17	117.9	2122.1	0	1705.6	107.7	1813.3	0
18	169.1	2291.2	0	1813.3	135.2	1948.5	0
19	118.3	2409.5	0	1948.5	131.7	2080.2	0
20	122.9	2532.4	0	2080.2	54.7	2134.9	0
21	208.2	2740.6	0	2134.9	75.4	2210.3	0
22	143.6	2884.2	0	2210.3	53.7	2264.0	0
23	214.7	3098.9	0	2264.0	61.9	2325.9	0
24	167.0	3265.9	0	2325.9	141.6	2467.5	0
25	85.2	3351.1	0	2467.5	136.2	2603.7	0
26	105.6	3456.7	0	2603.7	54.8	2658.5	0
27	136.5	3593.2	0	2658.5	118.8	2777.3	0
28	117.9	3711.1	0	2777.3	146.6	2923.9	0
29	160.2	3871.3	0	2923.9	167.8	3091.7	0
30	188.3	4059.6	0	3091.7	136.9	3228.6	0
31	108.0	4167.6	0	3228.6	81.4	3310.0	0
32	108.2	4275.8	0	3310.0	90.1	3400.1	0
33	98.4	4374.2	0	3400.1	149.7	3549.8	0
34	178.0	4552.2	0	3549.8	131.6	3681.4	0
35	135.7	4687.9	0	3681.4	70.0	3751.4	0
36	109.5	4797.4	0	3751.4	45.2	3796.6	0
37	206.5	5003.9	0	3796.6	117.3	3913.9	0
38	87.3	5091.2	0	3913.9	96.4	4010.3	0
39	138.5	5229.7	0	4010.3	69.8	4080.1	0
40	141.4	5371.1	0	4080.1	109.2	4189.3	0
41	103.5	5474.6	0	4189.3	13.2	4202.5	0
42	111.0	5585.6	0	4202.5	89.4	4291.9	0
43	132.3	5717.9	0	4291.9	80.7	4372.6	0
44	140.1	5858.0	0	4372.6	58.1	4430.7	0

45	110.9	5968.9	0	4430.7	91.7	4522.4	0
46	142.8	6111.7	0	4522.4	65.0	4587.4	0
47	79.6	6191.3	0	4587.4	76.1	4663.5	0
48	136.0	6327.3	0	4663.5	97.3	4760.8	0
49	99.6	6426.9	0	4760.8	109.1	4869.9	0
50	108.1	6535.0	0	4869.9	79.3	4949.2	0
51	110.1	6645.1	0	4949.2	104.9	5054.1	0
52	42.4	6687.5	0	5054.1	83.5	5137.6	0
53	121.6	6809.1	0	5137.6	42.6	5180.2	0
54	140.0	6949.1	0	5180.2	75.9	5256.1	0
55	132.7	7081.8	0	5256.1	92.7	5348.8	0
56	110.2	7192.0	0	5348.8	96.3	5445.1	0
57	148.6	7340.6	0	5445.1	104.4	5549.5	0
58	90.7	7431.3	0	5549.5	102.4	5651.9	0
59	129.9	7561.2	0	5651.9	98.9	5750.8	0
60	97.4	7658.6	0	5750.8	135.7	5886.5	0
61	98.6	7757.2	0	5886.5	75.7	5962.2	0
62	136.3	7893.5	0	5962.2	101.5	6063.7	0
63	73.0	7966.5	0	6063.7	121.2	6184.9	0
64	172.3	8138.8	0	6184.9	132.6	6317.5	0
65	95.7	8234.5	0	6317.5	79.4	6396.9	0
66	200.4	8434.9	0	6396.9	91.1	6488.0	0
67	95.7	8530.6	0	6488.0	77.2	6565.2	0
68	200.8	8731.4	0	6565.2	158.3	6723.5	0
69	149.3	8880.7	0	6723.5	145.1	6868.6	0
70	165.9	9046.6	0	6868.6	57.6	6926.2	0
71	145.9	9192.5	0	6926.2	42.6	6968.8	0
72	137.8	9330.3	0	6968.8	182.6	7151.4	0
73	59.5	9389.8	0	7151.4	61.6	7213.0	0
74	98.5	9488.3	0	7213.0	53.6	7266.6	0
75	167.6	9655.9	0	7266.6	71.2	7337.8	0
76	151.6	9807.5	0	7337.8	123.6	7461.4	0
77	129.8	9937.3	0	7461.4	85.7	7547.1	0
78	149.8	10087.1	0	7547.1	148.9	7696.0	0
79	73.6	10160.7	0	7696.0	118.3	7814.3	0
80	142.8	10303.5	0	7814.3	100.4	7914.7	0
81	131.2	10434.7	0	7914.7	103.7	8018.4	0
82	77.5	10512.2	0	8018.4	112.2	8130.6	0
83	0.0	10512.2	0	8130.6	77.4	8208.0	0
84	97.2	10609.4	0	8208.0	89.3	8297.3	0
85	148.5	10757.9	0	8297.3	48.9	8346.2	0
86	65.0	10822.9	0	8346.2	117.7	8463.9	0
87	124.8	10947.7	0	8463.9	33.0	8496.9	0
88	149.5	11097.2	0	8496.9	155.2	8652.1	0
89	168.8	11266.0	0	8652.1	70.1	8722.2	0
90	114.1	11380.1	0	8722.2	90.2	8812.4	0
91	117.6	11497.7	0	8812.4	105.3	8917.7	0
92	121.3	11619.0	0	8917.7	69.8	8987.5	0
93	67.5	11686.5	0	8987.5	98.6	9086.1	0
94	134.0	11820.5	0	9086.1	161.6	9247.7	0
95	102.1	11922.6	0	9247.7	0.0	9247.7	0
96	207.8	12130.4	0	9247.7	159.4	9407.1	0
97	182.2	12312.6	0	9407.1	145.1	9552.2	0
98	227.1	12539.7	0	9552.2	32.6	9584.8	0
99	186.3	12726.0	0	9584.8	98.4	9683.2	0
100	142.8	12868.8	0	9683.2	94.8	9778.0	0

Average wait time: 0.0
Average time in System: 5047.19
Probabilty of 50 customers in System: 0.52
Probabilty of Zero in Queue: 16.78
Average Customers in Queue: 0.0

```
In [2]:          'C:/Users/mujta/smsTest/Single_Server_Queue.py'       ='C:/Users/
mujta/smsTest'
Enter 1 for gaussian 2 for IID:

1
gaussian
Enter Mean:

56
Enter SD:

8
ID      IAT     Arr     Delay   Start   Serve   Exit    Queue
1       7.9     7.9     0.0     7.9     29.1    37.0    0
2       11.7    19.6    17.0    37.0    36.4    73.4    2
3       1.9     21.5    52.0    73.4    13.5    86.9    4
4       27.4    48.9    38.0    86.9    24.3    111.2   3
5       12.4    61.3    50.0    111.2   0.0     111.2   3
6       5.3     66.6    45.0    111.2   37.4    148.6   2
7       35.4    102.0   47.0    148.6   39.2    187.8   5
8       16.2    118.2   70.0    187.8   10.3    198.1   6
9       4.8     123.0   75.0    198.1   12.1    210.2   5
10      10.8    133.8   76.0    210.2   20.2    230.4   5
11      6.6     140.4   90.0    230.4   30.5    260.9   8
12      9.3     149.7   111.0   260.9   12.4    273.3   7
13      24.8    174.5   99.0    273.3   9.9     283.2   6
14      26.2    200.7   82.0    283.2   15.0    298.2   5
15      17.4    218.1   80.0    298.2   7.0     305.2   4
16      0.0     218.1   87.0    305.2   14.2    319.4   3
17      1.6     219.7   100.0   319.4   8.8     328.2   2
18      1.1     220.8   107.0   328.2   26.9    355.1   1
Average wait time: 68.11
Average time in System: 212.13
Probabilty of 10 customers in System: 0.73
Probabilty of Zero in Queue: 0.02
Average Customers in Queue: 3.94

In [3]:
```

IID Outputs:

```
Python 3.7.6 (default, Jan  8 2020, 20:23:39) [MSC v.1916 64 bit (AMD64)]
Type "copyright", "credits" or "license" for more information.

IPython 7.12.0 -- An enhanced Interactive Python.

In [1]:          'C:/Users/mujta/smsTest/Single_Server_Queue.py'       ='C:/Users/
mujta/smsTest'
Enter 1 for gaussian 2 for IID:

2
IID
Enter Max time delay between customers:

23
Enter Max time of Service:

45
```

ID	IAT	Arr	Delay	Start	Serve	Exit	Queue
1	2.2	2.2	0.0	2.2	2.8	5.0	0
2	3.4	5.6	0	5.0	30.9	35.9	0
3	2.1	7.7	28	35.9	40.4	76.3	2
4	20.7	28.4	48	76.3	11.6	87.9	4
5	11.9	40.3	48	87.9	2.5	90.4	3
6	21.0	61.3	29	90.4	18.8	109.2	3
7	4.6	65.9	43	109.2	31.6	140.8	3
8	22.7	88.6	52	140.8	27.3	168.1	5
9	10.6	99.2	69	168.1	35.4	203.5	8
10	20.9	120.1	83	203.5	11.0	214.5	11
11	12.6	132.7	82	214.5	3.7	218.2	10
12	5.2	137.9	80	218.2	15.8	234.0	10
13	14.5	152.4	82	234.0	33.2	267.2	10
14	10.2	162.6	105	267.2	13.3	280.5	11
15	0.9	163.5	117	280.5	9.0	289.5	11
16	2.5	166.0	124	289.5	3.2	292.7	10
17	12.5	178.5	114	292.7	16.1	308.8	9
18	3.7	182.2	127	308.8	33.4	342.2	10
19	1.1	183.3	159	342.2	24.8	367.0	12
20	18.2	201.5	166	367.0	25.2	392.2	13
21	16.2	217.7	174	392.2	2.1	394.3	13
22	15.4	233.1	161	394.3	20.2	414.5	12
23	20.0	253.1	161	414.5	35.3	449.8	12
24	7.1	260.2	190	449.8	31.2	481.0	15
25	18.1	278.3	203	481.0	16.3	497.3	15
26	21.6	299.9	197	497.3	33.0	530.3	18
27	4.4	304.3	226	530.3	9.6	539.9	20
28	21.4	325.7	214	539.9	18.6	558.5	20
29	7.1	332.8	226	558.5	20.3	578.8	20
30	5.9	338.7	240	578.8	21.3	600.1	20
31	15.6	354.3	246	600.1	28.6	628.7	20
32	5.3	359.6	269	628.7	3.8	632.5	22
33	18.8	378.4	254	632.5	8.1	640.6	21
34	21.7	400.1	240	640.6	44.9	685.5	21
35	19.9	420.0	266	685.5	19.0	704.5	27
36	18.2	438.2	266	704.5	9.5	714.0	26
37	6.0	444.2	270	714.0	6.4	720.4	25
38	4.7	448.9	272	720.4	29.8	750.2	24
39	13.3	462.2	288	750.2	22.1	772.3	23
40	22.1	484.3	288	772.3	25.6	797.9	22
41	5.7	490.0	308	797.9	41.6	839.5	21
42	1.4	491.4	348	839.5	3.7	843.2	20
43	4.9	496.3	347	843.2	33.6	876.8	19
44	1.4	497.7	379	876.8	23.9	900.7	18

```
45      10.4    508.1   393     900.7   40.9    941.6   17
46      12.2    520.3   421     941.6   43.4    985.0   16
47      15.2    535.5   450     985.0   25.4    1010.4  15
48      14.7    550.2   460     1010.4  26.3    1036.7  14
49      19.8    570.0   467     1036.7  0.2     1036.9  13
50      19.6    589.6   447     1036.9  24.4    1061.3  12
51      12.8    602.4   459     1061.3  32.1    1093.4  11
52      5.7     608.1   485     1093.4  9.6     1103.0  10
53      16.0    624.1   479     1103.0  43.7    1146.7  9
54      11.0    635.1   512     1146.7  17.5    1164.2  8
55      22.7    657.8   506     1164.2  37.7    1201.9  7
56      1.5     659.3   543     1201.9  33.4    1235.3  6
57      0.6     659.9   575     1235.3  18.0    1253.3  5
58      12.4    672.3   581     1253.3  27.4    1280.7  4
59      1.2     673.5   607     1280.7  39.1    1319.8  3
60      2.1     675.6   644     1319.8  19.4    1339.2  2
61      7.3     682.9   656     1339.2  13.0    1352.2  1
Average wait time: 266.79
Average time in System: 643.23
Probabilty of 30 customers in System: 0.46
Probabilty of Zero in Queue: 0.0
Average Customers in Queue: 12.66

In [2]:         'C:/Users/mujta/smsTest/Single_Server_Queue.py'      ='C:/Users/
mujta/smsTest'
Enter 1 for gaussian 2 for IID:

2
IID
Enter Max time delay between customers:

23
Enter Max time of Service:

9
ID      IAT     Arr     Delay   Start   Serve   Exit    Queue
1       18.4    18.4    0.0     18.4    1.9     20.3    0
2       11.4    29.8    0       20.3    0.9     21.2    0
3       3.8     33.6    0       21.2    2.7     23.9    0
4       10.6    44.2    0       23.9    4.7     28.6    0
5       4.0     48.2    0       28.6    1.9     30.5    0
6       20.3    68.5    0       30.5    4.9     35.4    0
7       9.1     77.6    0       35.4    3.7     39.1    0
8       17.2    94.8    0       39.1    8.9     48.0    0
9       14.7    109.5   0       48.0    6.1     54.1    0
10      21.5    131.0   0       54.1    6.8     60.9    0
11      19.0    150.0   0       60.9    4.4     65.3    0
12      15.7    165.7   0       65.3    8.5     73.8    0
13      18.3    184.0   0       73.8    2.1     75.9    0
14      8.5     192.5   0       75.9    7.8     83.7    0
15      14.3    206.8   0       83.7    7.2     90.9    0
16      19.8    226.6   0       90.9    4.6     95.5    0
Average wait time: 0.0
Average time in System: 52.94
Probabilty of 11 customers in System: 0.77
Probabilty of Zero in Queue: 11.54
Average Customers in Queue: 0.0

In [3]:         'C:/Users/mujta/smsTest/Single_Server_Queue.py'      ='C:/Users/
mujta/smsTest'
Enter 1 for gaussian 2 for IID:
```

```
2
IID
Enter Max time delay between customers:

56
Enter Max time of Service:

78
```

ID	IAT	Arr	Delay	Start	Serve	Exit	Queue
1	46.4	46.4	0.0	46.4	29.0	75.4	0
2	24.8	71.2	4	75.4	42.3	117.7	1
3	51.9	123.1	0	117.7	17.1	134.8	0
4	38.4	161.5	0	134.8	46.1	180.9	0
5	39.3	200.8	0	180.9	71.3	252.2	0
6	43.7	244.5	8	252.2	32.8	285.0	1
7	47.5	292.0	0	285.0	46.7	331.7	0
8	24.3	316.3	15	331.7	66.8	398.5	2
9	12.6	328.9	70	398.5	36.4	434.9	2
10	24.8	353.7	81	434.9	60.9	495.8	3
11	52.8	406.5	89	495.8	65.4	561.2	4
12	28.4	434.9	126	561.2	12.4	573.6	5
13	30.3	465.2	108	573.6	38.3	611.9	5
14	3.2	468.4	144	611.9	61.1	673.0	5
15	32.9	501.3	172	673.0	35.6	708.6	6
16	15.3	516.6	192	708.6	54.9	763.5	8
17	55.2	571.8	192	763.5	59.1	822.6	8
18	14.8	586.6	236	822.6	2.0	824.6	9
19	46.2	632.8	192	824.6	64.6	889.2	8
20	30.8	663.6	226	889.2	56.3	945.5	9
21	35.0	698.6	247	945.5	39.7	985.2	10
22	2.3	700.9	284	985.2	0.3	985.5	12
23	7.1	708.0	278	985.5	41.7	1027.2	11
24	41.9	749.9	277	1027.2	3.3	1030.5	11
25	28.7	778.6	252	1030.5	5.2	1035.7	10
26	41.4	820.0	216	1035.7	10.9	1046.6	9
27	9.4	829.4	217	1046.6	36.4	1083.0	9
28	49.8	879.2	204	1083.0	41.1	1124.1	10
29	16.6	895.8	228	1124.1	26.5	1150.6	10
30	34.3	930.1	220	1150.6	40.9	1191.5	10
31	16.8	946.9	245	1191.5	45.2	1236.7	10
32	9.0	955.9	281	1236.7	13.1	1249.8	11
33	8.4	964.3	286	1249.8	42.2	1292.0	11
34	28.8	993.1	299	1292.0	54.5	1346.5	11
35	51.2	1044.3	302	1346.5	14.0	1360.5	11
36	8.2	1052.5	308	1360.5	23.4	1383.9	10
37	22.8	1075.3	309	1383.9	71.5	1455.4	10
38	14.1	1089.4	366	1455.4	2.0	1457.4	10
39	51.1	1140.5	317	1457.4	39.9	1497.3	10
40	31.8	1172.3	325	1497.3	38.4	1535.7	10
41	22.9	1195.2	340	1535.7	65.7	1601.4	10
42	6.5	1201.7	400	1601.4	40.8	1642.2	13
43	36.7	1238.4	404	1642.2	63.3	1705.5	12
44	45.9	1284.3	421	1705.5	25.0	1730.5	14
45	40.3	1324.6	406	1730.5	37.5	1768.0	13
46	47.2	1371.8	396	1768.0	32.1	1800.1	13
47	33.0	1404.8	395	1800.1	41.5	1841.6	13
48	51.2	1456.0	386	1841.6	3.1	1844.7	13
49	18.8	1474.8	370	1844.7	40.6	1885.3	12
50	54.6	1529.4	356	1885.3	6.5	1891.8	11
51	40.9	1570.3	322	1891.8	14.8	1906.6	10
52	3.6	1573.9	333	1906.6	33.9	1940.5	9
53	14.3	1588.2	352	1940.5	4.7	1945.2	8

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54      10.7    1598.9  346     1945.2  44.2    1989.4  7
55      47.4    1646.3  343     1989.4  14.3    2003.7  6
56      48.0    1694.3  309     2003.7  24.8    2028.5  5
57      10.5    1704.8  324     2028.5  67.4    2095.9  4
58      43.7    1748.5  347     2095.9  17.7    2113.6  3
59      33.7    1782.2  331     2113.6  1.8     2115.4  2
60      45.9    1828.1  287     2115.4  43.3    2158.7  1
Average wait time: 241.4
Average time in System: 1209.4
Probabilty of 44 customers in System: 0.82
Probabilty of Zero in Queue: 0.11
Average Customers in Queue: 7.68

In [4]:
```