Names and ID of group members:

ESD 40.005 Mini Project
Due: Email Yunpeng and me by 11:59 pm on Friday March 18, 2016 (week 8)

- If you have not done so as yet, form teams of 5 students each and send me an email with your team member names and numbers (and Cc all team members).
- Pick a single-server queueing system with human customers. Make sure there is only one "stage" of service. If there are multiple stages, just focus on one. It is critical that the service process is one-by-one and the server does not serve more than one customer at a time. Some good options are: cashier counter at a fast-food restaurant, bank with a single teller, and MRT ticket counter. As soon as you decide on your queueing system, obtain permission from the concerned folks to allow you to collect data saying that its for an SUTD course dealing with queues. No two groups should collect data from the same location at the same time.
- To keep this project simple and tractable, *use the following additional guidelines*: do not consider queueing systems where you rarely see any queues building up; do not consider queues that are always non-empty; if you have many lines like in the grocery store or certain fast-food places, just pick one line and study that; do not consider systems that predominantly use batch arrivals or batch service; ignore customers that balk or reneg from the queue.
- Start collecting data to determine the inter-arrival distribution and the service distribution (you need to be careful here, before collecting data observe the system and understand what you would consider as *service*; same for inter-arrival time). Also collect data to estimate the waiting time. Collect plenty of observations so that your estimates are good. My recommendation would be about 100 customer arrivals. *Be sure that you start the data collection when the system is empty and end when the system is empty.* For best results be sure that the queue empties out several times during the data collection. Collect your data in one shot. If you must leave and return, make sure you start and end empty each time.

  For example, if one started observing a single server, infinite capacity, FCFS, queueing system at 13:00:00 hours, then the following could be the type of data collected:

Cust. number	time of arrival into the system	time of arrival at the server	time of departure from the system
1	13:00:10	13:00:10	13:00:11
2	13:00:56	13:00:56	13:01:08
3	13:01:12	13:01:12	13:01:22
4	13:01:17	13:01:22	13:01:30
5	13:01:33	13:01:33	13:01:58
6	13:01:36	13:01:58	13:02:03
7	13:01:37	13:02:03	13:02:08
8	13:01:46	13:02:08	13:02:09
⋮	⋮	⋮	⋮
100	13:42:56	13:42:56	13:43:02

  Tabulate your data and attach with your submission. Plot histograms of inter-arrival times and service times. **Do not plot histogram of waiting time**.

Answer the following:

1. For the inter-arrival times:
   (a) The mean is _____ seconds
   (b) The standard deviation is _____ seconds
   (c) The SCOV of inter-arrival time is $C_a =$ _____
   (d) The average arrival rate $\lambda =$ _____ per second
   (e) Based on the histogram and SCOV, the inter-arrival time distribution is (pick one) EXPONENTIAL or NON-EXPONENTIAL

2. For the service times:
   (a) The mean is _____ seconds
   (b) The standard deviation is _____ seconds
   (c) The SCOV of service time is $C_s =$ _____
   (d) The average service rate $\mu =$ _____ per second
   (e) Based on the histogram and SCOV, the service time distribution is (pick one) EXPONENTIAL or NON-EXPONENTIAL

3. Using the following approximate formula for the $G/G/1$ queue's mean time in the system (in theory) is
$$W \approx \frac{1}{\mu} + \frac{\lambda(C_a + C_s)}{2(1-\rho)\mu^2} = \text{\_\_\_\_\_ seconds}$$
where $\rho = \lambda/\mu$. *Note that for the $M/M/1$ and $M/G/1$ case the above formula is EXACT while it is an approximation for $G/M/1$ and $G/G/1$.* While there are other approximations, please use only this one.

4. The average time in the system using the sample data collected is _____ seconds.

5. Comment on how the theoretical result matched against the experimental result. Give some explanations and reasons, as appropriate.