Module 5 – Assignment

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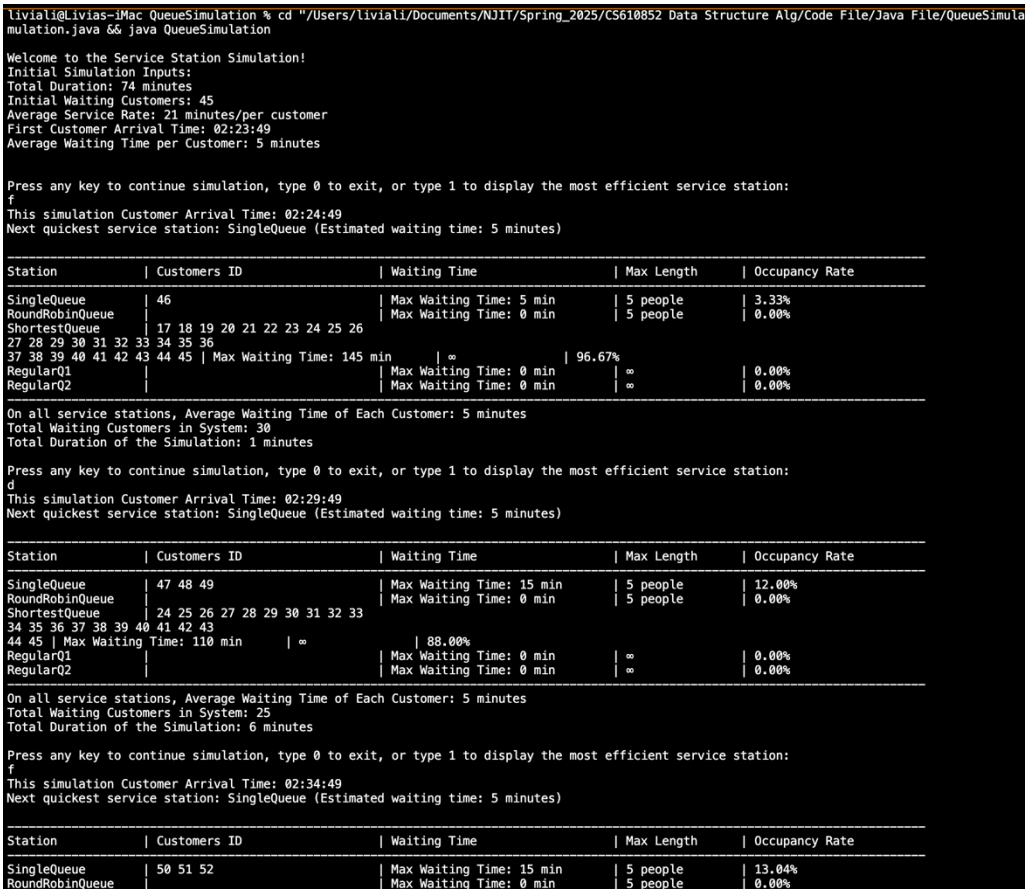
Screenshot of Simulation Program Output:



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liviali@Livias-iMac QueueSimulation % cd "/Users/liviali/Documents/NJIT/Spring_2025/CS610852 Data Structure Alg/Code File/Java File/QueueSimula
mulation.java && java QueueSimulation

Welcome to the Service Station Simulation!
Initial Simulation Inputs:
Total Duration: 74 minutes
Initial Waiting Customers: 45
Average Service Rate: 21 minutes/per customer
First Customer Arrival Time: 02:23:49
Average Waiting Time per Customer: 5 minutes


Press any key to continue simulation, type 0 to exit, or type 1 to display the most efficient service station:
f
This simulation Customer Arrival Time: 02:24:49
Next quickest service station: SingleQueue (Estimated waiting time: 5 minutes)

-------------------------------------------------------------------------------------------------------------------------------------------
Station            | Customers ID                  | Waiting Time                  | Max Length      | Occupancy Rate
-------------------------------------------------------------------------------------------------------------------------------------------
SingleQueue        | 46                            | Max Waiting Time: 5 min       | 5 people        | 3.33%
RoundRobinQueue    |                               | Max Waiting Time: 0 min       | 5 people        | 0.00%
ShortestQueue      | 17 18 19 20 21 22 23 24 25 26
27 28 29 30 31 32 33 34 35 36
37 38 39 40 41 42 43 44 45 | Max Waiting Time: 145 min      | ∞              | 96.67%
RegularQ1          |                               | Max Waiting Time: 0 min       | ∞               | 0.00%
RegularQ2          |                               | Max Waiting Time: 0 min       | ∞               | 0.00%
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On all service stations, Average Waiting Time of Each Customer: 5 minutes
Total Waiting Customers in System: 30
Total Duration of the Simulation: 1 minutes

Press any key to continue simulation, type 0 to exit, or type 1 to display the most efficient service station:
d
This simulation Customer Arrival Time: 02:29:49
Next quickest service station: SingleQueue (Estimated waiting time: 5 minutes)

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Station            | Customers ID                  | Waiting Time                  | Max Length      | Occupancy Rate
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SingleQueue        | 47 48 49                      | Max Waiting Time: 15 min      | 5 people        | 12.00%
RoundRobinQueue    |                               | Max Waiting Time: 0 min       | 5 people        | 0.00%
ShortestQueue      | 24 25 26 27 28 29 30 31 32 33
34 35 36 37 38 39 40 41 42 43
44 45 | Max Waiting Time: 110 min      | ∞              | 88.00%
RegularQ1          |                               | Max Waiting Time: 0 min       | ∞               | 0.00%
RegularQ2          |                               | Max Waiting Time: 0 min       | ∞               | 0.00%
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On all service stations, Average Waiting Time of Each Customer: 5 minutes
Total Waiting Customers in System: 25
Total Duration of the Simulation: 6 minutes

Press any key to continue simulation, type 0 to exit, or type 1 to display the most efficient service station:
f
This simulation Customer Arrival Time: 02:34:49
Next quickest service station: SingleQueue (Estimated waiting time: 5 minutes)

-------------------------------------------------------------------------------------------------------------------------------------------
Station            | Customers ID                  | Waiting Time                  | Max Length      | Occupancy Rate
-------------------------------------------------------------------------------------------------------------------------------------------
SingleQueue        | 50 51 52                      | Max Waiting Time: 15 min      | 5 people        | 13.04%
RoundRobinQueue    |                               | Max Waiting Time: 0 min       | 5 people        | 0.00%
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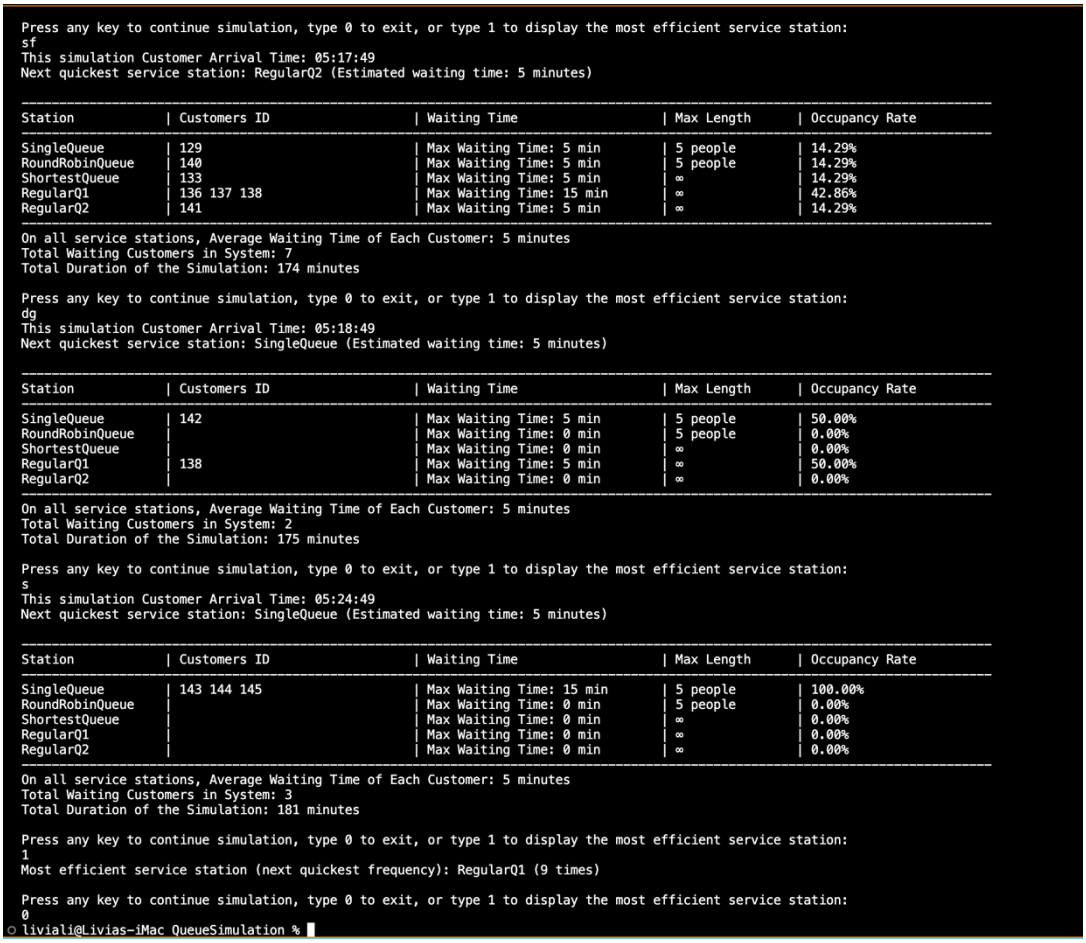

The simulation was designed to evaluate different queuing policies by modeling 5 interchangeable service stations where arriving customers are assigned to FIFO queues. The implementation uses multi-threading so that each station processes its queue independently (with a fixed 3-second processing delay per customer), while the main simulation loop dynamically generates customer arrivals over a randomly determined total duration (between 30 and 120 minutes). New customer arrivals are computed based on the duration of each round (on average, one new customer every 2 minutes) and the simulation continually updates the current “Customer Arrival Time” by adding the round’s duration to the previous time. The simulation outputs a neatly formatted table that shows, for each service station, the list of customer IDs, the maximum waiting time of current service station, the station’s maximum capacity (5 for SingleQueue and RoundRobinQueue and ∞ for the others), and an occupancy rate (the percentage contribution of each station’s waiting time relative to the system’s total waiting time).

The simulation system provides output key performance metrics such as total simulation duration, maximum queue length per station, average and maximum waiting times, and occupancy rates—allowing for an analysis of system efficiency under dynamic and crowded conditions.

According to the output of the simulation system, the ShortestQueue consistently builds up a high waiting time (e.g. 230 minutes in one round) and thus exhibits an occupancy rate of over 80%, indicating that it becomes overloaded and therefore inefficient under heavy load. In contrast, the SingleQueue and RoundRobinQueue tend to maintain lower occupancy rates (ranging from about 8% to 25%), although their usage depends on their capacity (I set them limited to 5 customers each in current system). Per the output, RegularQ1 was selected as the "next quickest" service station more frequently (with a frequency of 9 times) than the others. Even though its occupancy rate in rounds when it is active may be higher (around 40–42%), this consistent selection suggests that RegularQ1 is able to clear customers effectively—maintaining a low estimated waiting time (5 minutes) for new arrivals despite a higher load. Thus, while the occupancy metrics alone might suggest that a lower-loaded station (like RoundRobinQueue or SingleQueue) is "better," the fact that RegularQ1 is chosen more often for new assignments indicates that it is the most efficient option in terms of keeping overall waiting times low when the system is crowded.

Interestingly, this result ran counter to my initial intuition regarding the 5-service-station system. I originally expected that the ShortestQueue would prove most efficient—after all, it is designed to always accept new arrivals when it has the fewest customers. However, the simulation reveals that RegularQ1, despite sometimes operating at a higher occupancy level, is consistently selected as the next quickest station and ultimately demonstrates a more balanced performance in terms of waiting times. This outcome suggests that factors beyond simply having the fewest customers—such as the station's ability to process a heavy load efficiently—play a critical role in overall system performance.

This analysis confirms that by tuning the service rate to be much higher ($S \gg 5 \times A$), our simulation can indeed crowd the system and provide meaningful insights into the relative efficiency of each service station.