CS 150: Project I

Due: 11:55pm, Friday March 10, 2017

Introduction

Project Description

A popular coffee shop chain is opening a new coffee shop on College Hill. You are hired as a consultant to decide how many cashiers to hire in order to optimize the profit. The following conditions are known:

1. The shop opens at 6am and closed at 10pm. Use minute as the unit of time in this project.
2. There are s cashiers in the shop. When a customer arrives at the shop, he or she joins a single queue waiting to be served by the first available cashier, unless the length of the queue is more than $8s$, in which case the customer is turned away as an "overflow."
3. The estimated profit of serving each customer is p dollars.
4. The cost of employing a cashier is c dollars per day.
5. The arrivals of the customers follow a *Poisson distribution* with the parameter λ, which denotes the average number of customers arriving per minute (e.g., $\lambda = 2$ means 2 customers arrive per minute on average and $\lambda = 0.5$ means 0.5 customer arrives per minute on average—in other words, 1 customer arrives every 2 minutes). The Poisson arrival times of the customers can be generated by computing the intervals between consecutive arrivals using the following formula:

$$\text{arrivalInterval} = \frac{-\ln U}{\lambda},$$

   where U is a random variable drawn uniformly from $(0, 1]$.
6. The time required by a cashier to serve a customer follows an *exponential distribution* with the parameter r, which denotes the average number of customer served per minute (e.g., $r = 2$ means a cashier serves 2 customers per minute on average and $r = 0.5$ means a cashier serves 0.5 customer per minute on average—in other words, a cashier needs 2 minutes to serve a customer). The service time of a customer can be computed using a similar formula as above:

$$\text{serviceTime} = \frac{-\ln U}{r},$$

   where U is a random variable drawn uniformly from $(0, 1]$.

Assignments

As a consultant, your assignments are:

1. Write a program that can simulate, for any give set of parameters (s, p, c, λ, r), the arrival and departure times of all customer, the amount of daily net profit (total daily profit minus daily cost of cashiers), the rate of "overflow", the average and maximum waiting time of all customers served.
2. Fix $p = 2$, $c = 300$, and $r = 0.3$. For each of $\lambda = 2,\ 1.5,\ 1,\ 0.5,\ 0.3,\ 0.2$, plot the net daily profit as a function of the number of cashiers s. You should run at least 5 simulations for each configuration.
3. For each of $\lambda = 2,\ 1.5,\ 1,\ 0.5,\ 0.3,\ 0.2$, find the optimal number of cashiers s that maximizes the profit. Plot a graph of the optimal number of cashiers as a function of λ.

Guidelines

1. You should use the appropriate data structures and algorithms. Specifically, the following data structures are used in this project: ArrayList, LinkedList, Queue, PriorityQueue.
2. The simulation is "event-driven", that is, the simulation processes events such as customer arrivals and departures in order of time. The customer arrivals are computed in advance and stored in a priority queue in order of time. When a customer is served, the service time is generated using the given formula, the customer's departure time is computed, and the departure event is inserted into the priority queue. In each iteration of the simulation, the event in the head of the priority queue is removed and processed.
3. Your conclusions and analysis should be supported by data from your simulations.

Report

The guideline for wiring the project report is attached below.

Grading

The project is to be completed individually. Unless otherwise approved by the instructor, the only person you can consult is the instructor. Your project will be graded on the following criteria (assuming the program compiles and runs):

1. correctness of the program
2. documentation (methods and classes) including javadoc
3. unit testing
4. object oriented design
5. quality of the simulation and analysis
6. quality of the project report

CS 150: Guidelines For Writing Lab and Project Reports

Version as of: 22:06 Sunday 31st July, 2016

Description

Your lab and project reports all have the same structure. The main differences lie in the complexity of the problem, the amount of data generated, the subsequent analysis and the length of the report. The lab reports have a minimum length of 3 pages and the project reports have a minimum length of 5 pages. The structure of a report has the following (numbered) sections:

1. Introduction - This introduces the problem that you are trying to solve. What are the goals? What assumptions did you make?
2. Approach - This section describes your approach to solving the problem. Example: design of the program, choice of algorithm and data structure. Include the design/architecture including the classes and the functionality/purpose of each class. Do not include a description of the methods.
3. Methods - This section describes your experimental setup. Example: how many runs, what parameters did you use, why the particular choice of experimental setup, parameter values
4. Data and Analysis - This section describes the data that you obtained (plotted) and your analysis of the data.
5. Conclusion
6. References - Books, websites, project descriptions, APIs that you used for the experiment/project. These references **must** be cited within the body of the report.

Figures, Tables and References

There are additional requirements for each report:

1. Each figure and table must be labelled and have (short)legends that describe the table. Discussions and descriptions in the text should refer to the tables and figures as Figure 1, Table 2, etc.,
2. Figures should have labels on the axes and the units for each axis should be clearly shown.
3. Each item in the reference section should be cited in the text.

All lab and projects reports **MUST** follow the above structure.