IE 306.02 - System Simulation

Homework 3

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Contents

1 Introduction

1.1 Description

For this homework, we are expected to create a model for the simulation of moviegoers in a cinema. There exist 3 movies, which are *Decalogue-1*, *The Clone Wars: Ashoka's Return*, and *Vavien* and each movie is shown once a day. People come to the cinema in groups of 2,3 or 4 people, each of them with equal probability. There exists one counter for each film, or one for all based on the scenario and each groups takes 2,3 or 4 tickets for the same movie from the counter, according to the size of that group. If there is no ticket left for that film, other movies are checked following the alphabetical order of the movie titles. Each group decides which movie to go to or figures out there's no tickets left for any film in one minute of decision time. Since the minimum size of a group is 2, if there is less than 2 ticket left for any film, it's called *sold out*. If all of the movies become sold out, the people renege from the related queues. The operation time of the counter is 150 minutes, and service time of the counter is 1 minute for each member of the group.

1.2 Assumptions

- Local cinema displays 3 movies at 3 theatres: Decalogue-1', The Clone Wars: Ashoka's Return, and Vavien, and their movie ids in the simulation are 1,2,3 respectively which are matched based on the alphabetical order.
- The entity of the simulation is the Moviegoers which is essentially a group of 2,3 or 4 people.
- Moviegoers decide on a movie with equal probability and this decision time takes exactly 1 minute. This time includes trying all movies in the sequential order of names until finding a non-soldout movie.
- If a non-soldout movie exists, the counter sells the tickets to the Moviegoers and this takes exactly 1-minute.
- In each scenario, we have run the simulation for 30 independent replications and created confidence intervals for the collected statistics at a confidence level of %95.

1.3 Simulation Logic

At first, by 'create moviegoer' module we are creating entities that along the way going to have attributes such as numTickets which indicates the # of people in the group, the movie they want to see(movieNo) and numTriedMovies which indicates the # of movies that they tried to enter. After that, they go to assigned movie number by the 'which movie' module. In the line that

are directed to, they will increase the number of people in the queue by the numTickets they have. Then, they will be recorded to the Queue counter of the designated movie. After that, the number of people will be decreased as much as the people in the group because they will get into the process of whether they will be able to get into the movie or not. They will also have delay in the beginning of the process in order to make the movie decision.

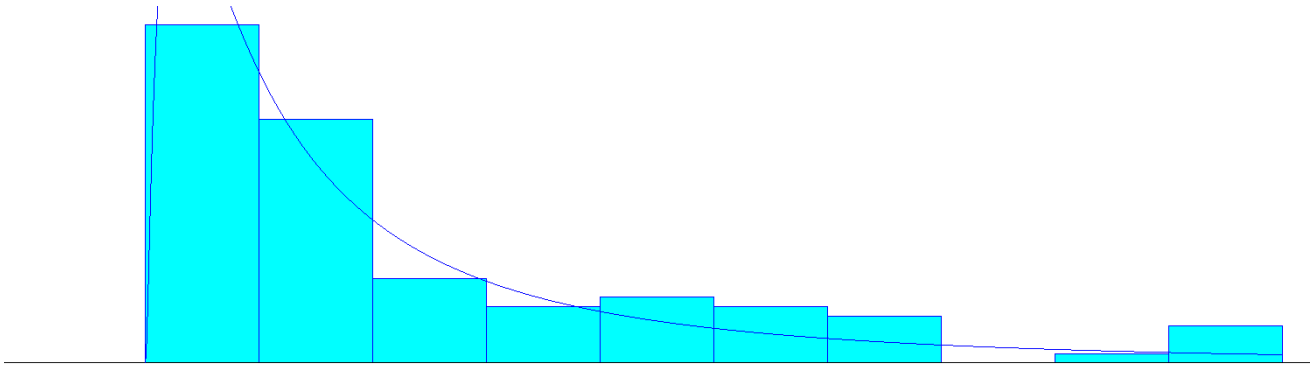
For the second part, if it is first movie they will get into the module 'Have enough tickets left for M1' if the answer to that question is no, they will be directed to 'Are all movies tried' for the sake of making them go to other available movies. During the process, the movie they tried to get in but couldn't be recorded. On the other hand, when the answer is yes, people who watches the movie will be increased and the number of tickets left for the movie to be sold will decrease. Later, it will check whether the movie is sold out or not by checking the numlefttickets is equal or smaller than 1. If it is sold out, for the further part, in the first movie we have an additional step because we need to check whether 'Decalogue-1' is full before other movies. By the film counter(this is updated in 'num of soldout movies' module) which gives us the information how many movies sold out so far, it determine whether it is first one to be sold out by checking the number whether it is zero or not. Time will also be recorded.

For the third part, we will move along with the aftermath of soldout case. The people who are waiting in the queue to get in the movie will need to get removed and released in two separate procedures as it can be seen in the module chart. After the removing process since we need to check the average number of people that renege when all movies are sold out we look whether the movie we are dealing with is rather the last one to be sold out. If that is the case the people removed(renege also) will be recorded finally.

Three counter case and one counter case is basically the similar apart of process is going through different number of counter(s) for both cases.

1.4 Input Analysis

When we run the Input Analyzer in Arena to fit the best distribution to the given Interarrival times data, we have found that the data is distributed Log-Normally with $\mu = 134$ *seconds* and $\sigma = 258$.



```
       Distribution Summary

Distribution:   Lognormal
Expression:     LOGN(134, 258)
Square Error:   0.007709

Chi Square Test
  Number of intervals   = 4
  Degrees of freedom    = 1
  Test Statistic        = 5.26
  Corresponding p-value = 0.0228

Kolmogorov-Smirnov Test
  Test Statistic        = 0.0781
  Corresponding p-value > 0.15

       Data Summary

Number of Data Points   = 100
Min Data Value          = 0.378
Max Data Value          = 453
```

Figure 1.1: Fitting a Distribution using Arena Input Analyzer

2 Analyzing Arena Reports

We are expected to run our simulation in three scenarios and each scenario is run with 30 independent replications. Since Arena constructs %95 confidence intervals for each statistics, we have recorded the necessary statistics within Arena, will base our interpretations on the output reports of Arena.

2.1 Scenario 1: Single Counter run for 150 Minutes

- **Average time before Movie 1 is sold out(M1SoldoutTime):** $37.5015 \pm 5,07$
- **Average time before Movie 2 is sold out(M2SoldoutTime):** $38.6341 \pm 4,13$
- **Average time before Movie 3 is sold out(M3SoldoutTime):** $36.6777 \pm 5,30$
- **Average number of people that renege when all movies are sold out (RenegedsAfterLastSoldOut):** $1.4667 \pm 0,67$
- **Average number of people that leave the theatre due to closing of the counters(NumPeopleInQueueWhenCountersClose):** $0.3667 \pm 0,44$
- **Average number of people that watch Movie 1(Movie1Watchers):** $9.7333 \pm 0,17$
- **Average number of people that watch Movie 2(Movie2Watchers):** $9.6667 \pm 0,18$
- **Average number of people that watch Movie 3(Movie3Watchers):** $9.7333 \pm 0,17$
- **Proportion of time 'Decalogue-1' is full before other movies:** $8.1902 \pm 4,51$
- **Proportion of time ticketcounter(s) is(are) idle:** We can calculate the proportion of idleness by subtracting the interval of number of busy units in the counters from 1 since the resource can be only 0 or 1.
  - **Idleness of Counter:** $1 - (0.5836 \pm 0.04) = 0.4164 \pm 0.03$

2.2 Scenario 2: Three Counters run for 150 Minutes

- **Average time before Movie 1 is sold out(M1SoldoutTime):** $96.9160 \pm 14,61$
- **Average time before Movie 2 is sold out(M2SoldoutTime):** $90.9379 \pm 14,99$
- **Average time before Movie 3 is sold out(M3SoldoutTime):** $89.8460 \pm 14,75$
- **Average number of people that renege when all movies are sold out (RenegedsAfterLastSoldOut):** $0.400 \pm 0,33$

- **Average number of people that leave the theatre due to closing of the counters (Movie1)(NumPeopleInQueue1WhenCountersClose):** $0.1000 \pm 0,20$
- **Average number of people that leave the theatre due to closing of the counters (Movie2)(NumPeopleInQueue2WhenCountersClose):** $0.06666667 \pm 0,09$
- **Average number of people that leave the theatre due to closing of the counters (Movie3)(NumPeopleInQueue3WhenCountersClose):** $0.3000 \pm 0,38$
- **Average number of people that watch Movie 1(Movie1Watchers):** $48.2000 \pm 2,01$
- **Average number of people that watch Movie 2(Movie2Watchers):** $48.9333 \pm 0,81$
- **Average number of people that watch Movie 3(Movie3Watchers):** $48.6333 \pm 1,39$
- **Proportion of time 'Decalogue-1' is full before other movies:** $34.6138 \pm 18,02$
- **Proportion of time ticketcounter(s) is(are) idle:** We can calculate the proportion of idleness by subtracting the interval of number of busy units in the counters from 1 since the resource can be only 0 or 1.
  - **Idleness of Counter 1:** $1 - (0.4704 \pm 0.03) = 0.5296 \pm 0.03$
  - **Idleness of Counter 2:** $1 - (0.4578 \pm 0.03) = 0.5422 \pm 0.03$
  - **Idleness of Counter 3:** $1 - (0.4741 \pm 0.04) = 0.5259 \pm 0.04$

2.3 Scenario 3: Three Counters run for 50 Minutes

- **Average time before Movie 1 is sold out(M1SoldoutTime):** 0 (not enough time to be soldout)
- **Average time before Movie 2 is sold out(M2SoldoutTime):** 0 (not enough time to be soldout)
- **Average time before Movie 3 is sold out(M3SoldoutTime):** 0 (not enough time to be soldout)
- **Average number of people that renege when all movies are sold out (RenegedsAfterLastSoldOut):** 0 (not enough time to be soldout)
- **Average number of people that leave the theatre due to closing of the counters (Movie1)(NumPeopleInQueue1WhenCountersClose):** $0.3333 \pm 0,23$
- **Average number of people that leave the theatre due to closing of the counters (Movie2)(NumPeopleInQueue2WhenCountersClose):** $0.5333 \pm 0,31$
- **Average number of people that leave the theatre due to closing of the counters (Movie3)(NumPeopleInQueue3WhenCountersClose):** $0.9000 \pm 0,52$
- **Average number of people that watch Movie 1(Movie1Watchers):** $21.3333 \pm 2,88$

- **Average number of people that watch Movie 2(Movie2sWatchers):** $19.4333 \pm 3,47$
- **Average number of people that watch Movie 3(Movie3Watchers):** $22.8000 \pm 3,34$
- **Proportion of time 'Decalogue-1' is full before other movies:** We can calculate the proportion of idleness s
- **Proportion of time ticketcounter(s) is(are) idle:** We can calculate the proportion of idleness by subtracting the interval of number of busy units in the counters from 1 since the resource can be only 0 or 1.
  - **Idleness of Counter 1:** $1 - (0.5618 \pm 0.07) = 0.4382 \pm 0.07$
  - **Idleness of Counter 2:** $1 - (0.5051 \pm 0.09) = 0.4949 \pm 0.09$
  - **Idleness of Counter 3:** $1 - (0.5900 \pm 0.09) = 0.41 \pm 0.09$

3 Comparison of Scenarios and Conclusion

Among the three scenarios, the two differing features are the # of counters and the simulation run time. When we look at the Scenario 1, we can see that each movie is soldout before 43 minutes within the %95 confidence interval. Since all other customers are reneged, there is no need for the counter to be employed 150 minutes. This is waste of time and resource. Therefore, it may be advised to the theatre to decrease the working time of the counter significantly. When we look at the idleness of the counter, we can see that it is busy around %58 of the time. Therefore, we can say that there is no need for more counters to sell everybody ticket before counters close. When we look at the Scenario 2, we can see that each movie is soldout before 111 minutes within the %95 confidence interval. Since all other customers are reneged, there is no need for the counter to be employed 150 minutes. This is waste of time and resource. Therefore, it may be advised to the theatre to decrease the working time of the counter maybe down to 120s. In this case, we have three counters. When we look at the idleness of these counters, we can see that they are idle half of the time. It may be advised to decrease the # of counters in this scenario. When we look at the Scenario 3, we can see that none of the movies are sold out. This is due to the end time of the theatre. This situation is not profitable for the theatre and they would sell more tickets if they would be open more time as in Scenario 2. Idleness of the counters are similar to Scenario 2, and may be reduced to increase profit.

When it comes to estimating the relative performance between these three terminating scenarios statistically, since random numbers are equal in each scenario, one method is to do a Correlated Sampling Approach among each two scenarios. In that approach, we take the differences of the selected performance measure, then calculate the standard error and the mean of those differences and construct the %95 confidence interval. This approach would be run for waiting times of each entity which is an important performance measure if it would be possible to get that data out of ARENA.