Model of a Common Fast Food Restaurant

A Discrete-Event Simulation including 2D Animation

Abstract

Restaurants often wish to see how the number of employees working during a given shift affects the profit and payroll for that shift. Ideally, profit should be maximized and payroll should be minimized. Process Interaction can be used to model the restaurant and Discrete-Event Simulation can be used to produce reasonable values for profit and payroll.

Introduction

We plan to model the largest fast food chain in America - Subway. Subway is a sandwich chain which typically has a maximum of 3 employees working at any time. Customers arrive, look at a menu, place their order with the first available employee on the line, and pay with the employee at the register. Having paid for their order, customers may either choose to eat in or take it to go.

Customers arriving at a restaurant generally do so at random, so we plan to use a Poisson interarrival time. Poisson processes possess the following traits: Arrivals occur one at a time, arrivals are completely random, future arrivals are occur independently. We believe these characteristics accurately represent the arrivals at a restaurant.

After arrival, customers proceed to be serviced by the first available employee. The arrival rate of the register queue depends on the service rate of the order queue. Service times for both queues are to be modeled using an Exponential distribution. We believe this to be correct because, although most employees are able to complete tasks around a theoretical average, there are cases where the actual, measured service time greatly differs from the average.

These statistics can be applied to our two queues using the same queuing mode for verification: the M/M/c Queue. The random chance that a customer may enter the lobby to eat does not need a queue, since the customer will not wait for seats to become available if the lobby is full. While a "sit-down" restaurant might have a queue outside before customers enter the restaurant, customers of fast food restaurants are unlikely to wait to be seated.

The payroll and profit for the restaurant can be calculated using the following objective functions:

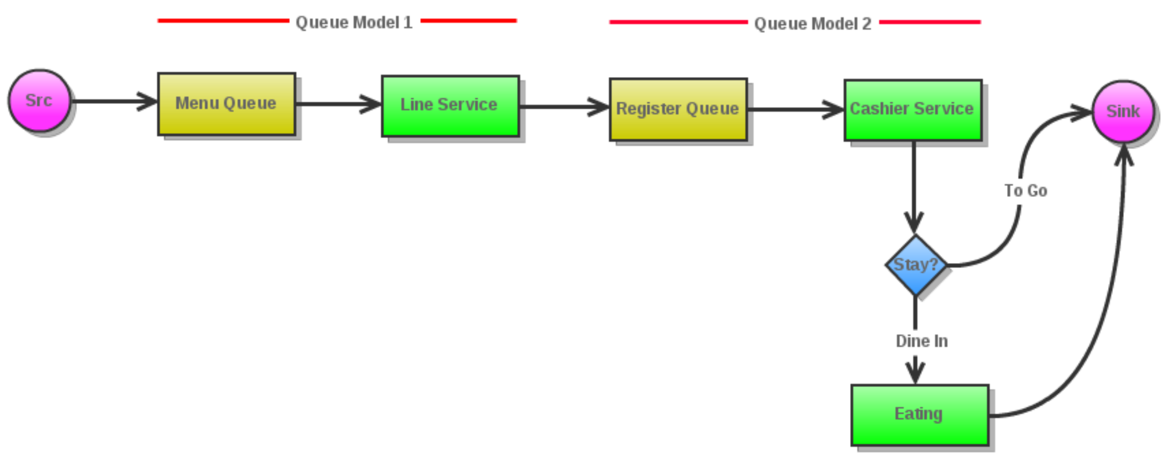
$$payroll(n_E, t) = \$7.5 \times n_E \times t + 1$$
$$profit(n_C, n_E, t) = \left(\$5 - \max\left(w_{Q_{line}}, w_{Q_{register}}\right)\right) \times n_C - payroll(n_E, t)$$

Assumptions

- Each employee earns minimum wage
- The restaurant can only seat 24 customers (2/table * 12 tables)
- Each customer only orders one menu item
- All menu items cost the same amount ($5.00)
- Exponential interarrival times (Poisson Process)
- Exponential service times
- 2x M/M/c queues

Simulation Schematic

Here is the simulation schematic for our proposed simulation. To keep the schematic simple, we represent services as single boxes. In the actual simulation, these services are subdivided depending on the number of people servicing a particular service.

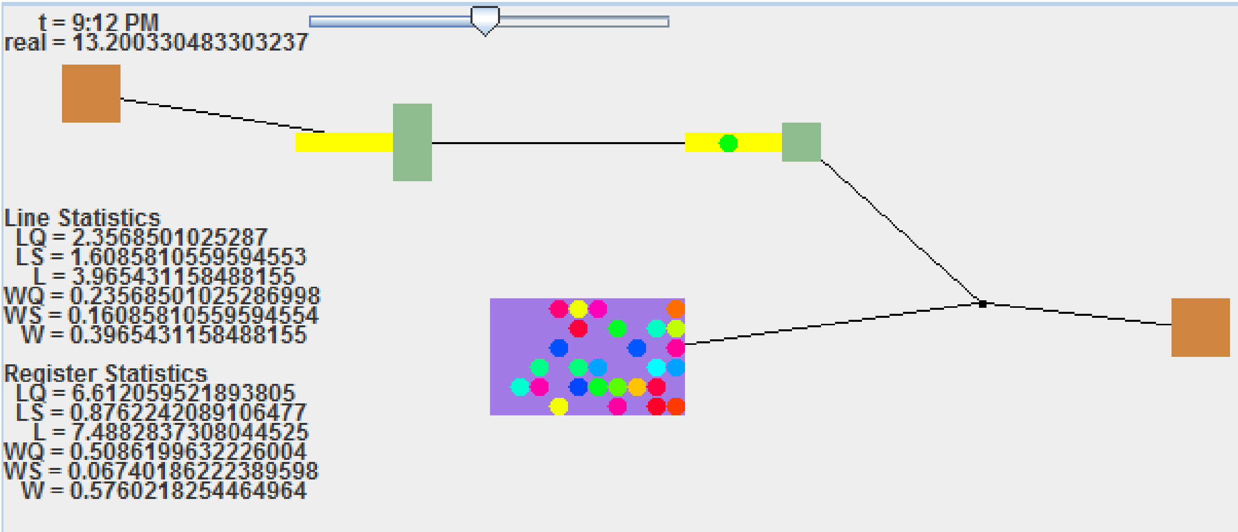


Discrete Modeling Plan

We will implement our model using a Process Interaction Simulation Engine, written in the Scala Programming Language, developed for an earlier class project. More information on Process Interaction can be found in Discrete-Event System Simulation: 5/e by Banks et al. [1]

Animation Component

The Process Interaction simulation will include a 2D animation component written in Swing and possibly various other graphics and animation libraries. The animations will be timed such that they are both interesting to watch and representative of the simulation. The purpose of these animations is to show the behavior of the system.



Model Verification

In order to verify our model with the Jackson Queuing Network code provided in the ScalaTion, we limited the number of line workers and cashiers to one each. We also set the stop time on the simulation to thirty-two hours (representing four eight-hour shifts) and generated the following ten replications:

	LINE			**REGISTER**		
	W_Q	W_S	W	W_Q	W_S	W
	0.1394	0.1309	0.2703	0.1114	0.1134	0.2248
	0.3412	0.1351	0.4762	0.1161	0.1111	0.2272
	0.2149	0.1204	0.3353	0.0335	0.0875	0.121
	0.1457	0.1174	0.2631	0.0772	0.1078	0.185
	0.1638	0.1205	0.2843	0.1309	0.0965	0.2274
	0.134	0.1166	0.2506	0.1233	0.0983	0.2216
	0.2101	0.1238	0.3339	0.0981	0.0977	0.1958
	0.5202	0.1541	0.6743	0.1417	0.1006	0.2423
	0.3392	0.1295	0.4687	0.0743	0.0945	0.1688
	0.3355	0.1343	0.4698	0.0871	0.0934	0.1805
Sum	2.544	1.2826	3.8265	0.9936	1.0008	1.9944
Average	0.2544	0.12826	0.38265	0.09936	0.10008	0.19944
Variance	0.015913342	0.000128363	0.018606032	0.001043807	6.82662E-05	0.001355076
Std. Dev.	0.126148096	0.011329725	0.136403928	0.032308004	0.008262338	0.036811357
$C_{\alpha=0.05}$	0.078185963	0.007022107	0.084542477	0.02002434	0.005120956	0.022815496
CI-MIN	0.176214037	0.121237893	0.298107523	0.07933566	0.094959044	0.176624504
CI-MAX	0.332585963	0.135282107	0.467192477	0.11938434	0.105200956	0.222255496
Theory	0.208	0.125	0.333	0.1	0.1	0.2

Since the absolute value of the difference between the actual and theoretical averages for each of these statistics is less than the confidence half-width (with α=0.05), we can be 95% confident that the simulation will produce averages within the confidence interval.

Results

The results of our verification simulation are provided below. It is important to remember that n_E is fixed at two in the following results:

	n_C	$payroll$	$profit$
	143	495.00	200.07
	167	495.00	283.03
	151	495.00	227.55
	146	495.00	213.73
	165	495.00	302.98
	166	495.00	312.75
	185	495.00	391.13
	178	495.00	302.40
	152	495.00	213.44
	158	495.00	241.99
Sum	1611	495.00	2689.07
Average	161.1	495	268.907
Variance	186.766667	0	3626.380912
Std. Dev.	13.6662602	0	60.21943965

We also ran a couple long-run simulations (with a stop times of 1000) in order to see the impact different numbers of employees have on profit. We neglect the cost of payroll because it is deterministic based on the total number of employees working over a time period. In the table below, each row represents the average of ten runs for a particular combination of $\boldsymbol{n_{E_{line}}}$ and $\boldsymbol{n_{E_{register}}}$. Also, the max for $\boldsymbol{n_{E_{line}}}$ and $\boldsymbol{n_{E_{register}}}$ are three and two, respectively.

$\boldsymbol{n_{E_{line}}}$	$\boldsymbol{n_{E_{register}}}$	$\overline{\boldsymbol{n_C}}$	$\overline{\boldsymbol{profit}}$	Variance	Std. Dev.
1	1	4996.4	8866.084	234214.6	483.9573
1	2	5018.9	1513.143	83323.58	288.6582
2	1	4988.3	1917.085	48819.84	220.9521
2	2	5011.9	-5039.59	107618.1	328.052
3	1	5024.4	-5402.08	83523.38	289.0041
3	2	5006.8	-12538.1	85117.16	291.7484

Conclusions and Future Work

The results of our simulation have shown that maximum profit can be gained, given the model provided, by employing only a single line worker and cashier.

Future work may include:

- Modifying the objective functions in order to more accurately describe how payroll and profit are calculated.
- Extending the menu selection.
- Adding different service-time distributions for employees with more experience or training.
- Use different optimization techniques minimize the payroll function and maximize the profit function.

References

[1] Banks, Carson, Nelson and Nicol, “Discrete-Event System Simulation: 5/e”, 2010