Lab 2: Hospital Emergency Room queue simulation

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Introduction

The aim of this lab is to simulate a queueing system that can well represent a hospital with an urgency management system. The arrivals are independent of each other, so it is assumed that they follow a Poisson distribution with a fixed λ. The patients are then classified according to their urgency, as would be done in a hospital emergency room. We simulate the system to receive 1/6 of the patients as very urgent (red code), 1/3 of the patients as moderately urgent (yellow code), and 1/2 of the patients as not urgent (green code).

The hospital processes patients with a strict priority discipline. The most urgent patients are treated first. When a red code enters the system and a yellow or green code is in service, the latter is interrupted and the service of the just arrived red code is started immediately. The interrupted service will be resumed later on. When a red client leaves and a service of a green client has been interrupted, his service can be resumed even if a yellow client is currently waiting. This is not happening if there is a red client waiting, the green paused client has to wait the process of the red one.

The service times are also independent of each other and random, so it is also assumed that they follow a Poisson distribution. The system assumes that, on average, red code patients need more time than yellow code patients and yellow code patients need more time than green code patients. This logic is then used to adjust the μ based on the urgency of the patient.

The simulation takes as input parameters the Arrival λ, the Service μ (which is a base μ parameter then adjusted for the differences based on the urgency), the number of doctors (number of servers c), and the Simulation Time.

Expected behaviour

This queuing system is a variant of the **M/M/c queuing system**. It introduces variety in how clients are processed with the addition of urgency discipline, but however, we can assume some expected behaviour based on the property of this type of queuing system.

Knowing that an **M/M/c queue system** is stable when the average arrival rate of clients is less than or equal to the capacity of the system, and that the stable condition is:

$$\lambda < c \cdot \mu$$

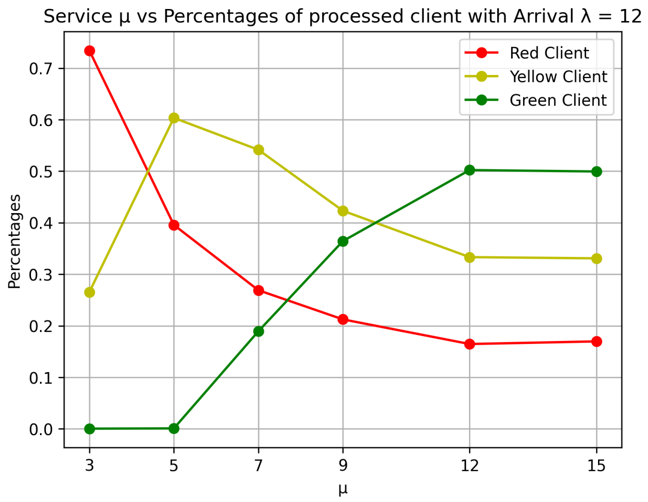
we can assume that when we have only one doctor ($c = 1$) and $\lambda > \mu$, the system will tend to fill the queue more and process mostly the most important patients (red and yellow). This is because in this state the arrival rate is so high that the system cannot process clients quickly enough, and priority discipline will ensure that the clients it does manage to process are the most urgent.

We can also assume that when we have only one doctor ($c = 1$) and $\lambda < \mu$, the system will be able to process all the arrival clients without difficulties and that the departure process will be similar to the arrival process (so with 1/6 red-client, 1/3 yellow-client and 1/2 green-client).

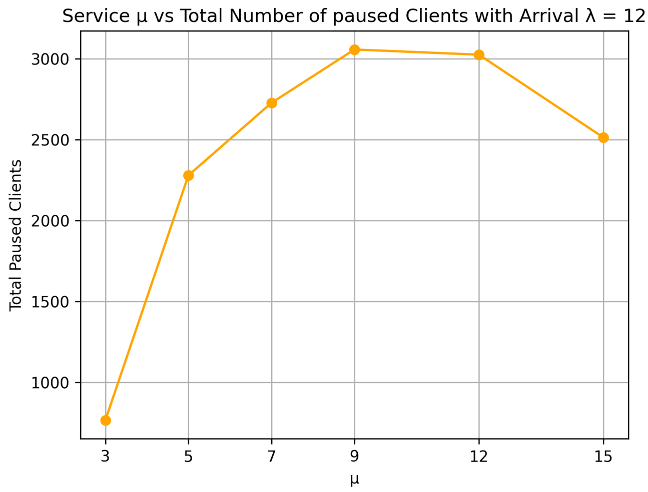
We can make similar assumptions when we have more than one doctor ($c > 1$) according to the formula.

Simulation results

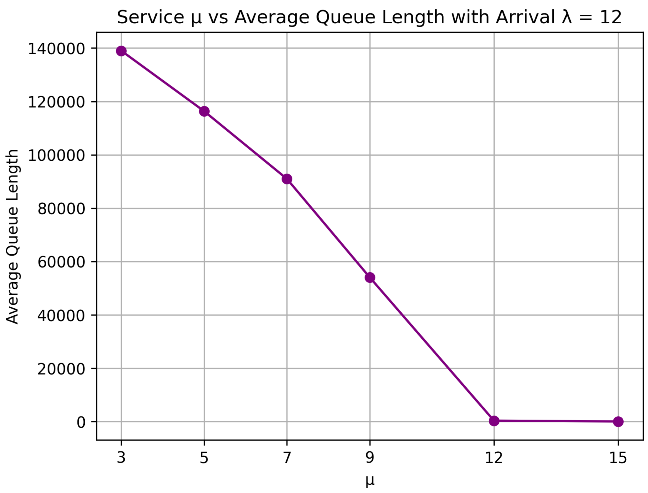
The simulation results confirm the hypothesis that when the arrival rate is higher than the service rate (when $\lambda > c \cdot \mu$), the system will have difficulty processing all the arriving clients and it will prioritise the most urgent clients. As we can see in figure 1(a), the majority of the percentage of total clients processed are red. As the system becomes more and more stable, we can see that it is able to start processing green clients and when it reaches the stability condition ($\lambda = \mu$) it reaches a situation where the departure percentage of each type of client is almost identical to their arrival percentage.



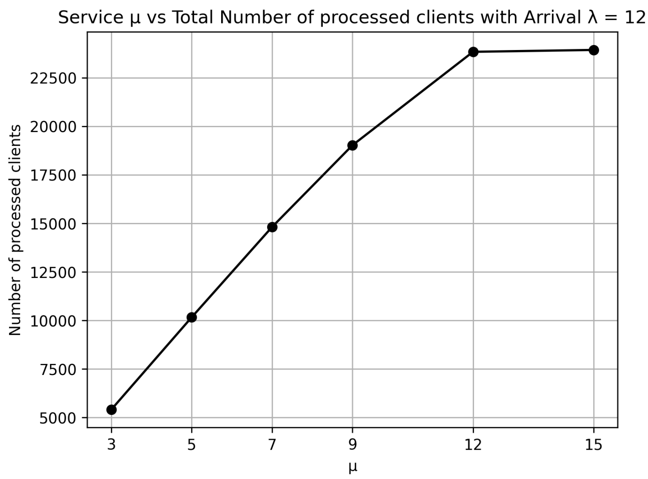
(a)



(b)



(c)



(d)

Figure 1: Simulations results plots with $c = 1$ and $SimulationTime = 2000$

In Figure 1(b) it can be seen that when the system is not stable, the number of clients that has been paused is very low. This suggests that when the system starts to become overcrowded and starts to prioritise the urgent clients, it only processes urgent ones without ever starting to process low urgency clients.

The other graphs show the common behaviour that **M/M/c queue system** have. In Figure 1(c) it can be seen that the Average Queue length is decreasing as the Service μ increases as the system becomes more capable of handling the clients that arrive. It can be seen in Figure 1(d) how the Total Number of processed clients increase as the Service μ increase.

Conclusions

The simulation is able to behave according to the **M/M/c queueing** theory and can provide useful information on how a real hospital emergency room scenario might look.