Prediction of queue waiting times

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Abstract—Queuing theory is a branch of mathematics that studies, analyses and predicts the behaviour of queues using queuing models. Even though queuing models were originated in the early 1900s, they are not widely used in modern times. This project uses the Poisson distribution together with exponential distribution and other probability techniques to implement a queuing model that can predict the behaviour of queues and estimate the expected customer waiting times.
The project also involves the implementation of a queue management system that controls simulated queues. The system can be monitored with dashboards that provide real-time data about the queues and alerts that are set off when a queue exceeds a previously defined limit.
Python is used to implement the queuing model, and the simulations are made in the discrete-event simulation framework SimPy, that is based on Python. On the other hand, the dashboards used to monitor the system are created in PowerBI using real-time data.

Index Terms— behaviour of a queue, discrete event, exponential distribution, monitorization, M/M/1, Poisson, Python, queue management system, SimPy

1 Introduction

AMUSEMENT parks are popular destinations for people seeking entertainment and adventure. These parks offer a wide range of attractions, from breathtaking rollercoasters to family rides. However, there's something that frustrates everyone: long queues. Queues can lead to a negative experience of the park and can cause discomfort to the visitors.

This project focuses on a big amusement park that has this exact problem. The understanding of the behaviour of its queues is needed in order to find alternatives that can provide the fast services visitors demand. Understanding how queues work and being able to predict them can optimize processes and increase the visitor's satisfaction.

In the project the principal objective is to accurately predict waiting times. In order to do so, a queuing model is implemented using Poisson and exponential distribution along with other probability techniques. Additionally, a queue management system is designed to control queues simulated in the SimPy framework [1]. By implementing and monitoring the system using dashboards the behaviour of the queue can be understood and, therefore, different options for improving the queuing system can be contemplated.

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2 Objectives

After defining and analyzing the problem to be solved, a series of objectives are outlined to successfully conclude this project:

- Accurately predict queue waiting times.
- Control simulated queues using an easily scalable queue management system.
- Monitor the system with dashboards.
- Propose alternatives that can reduce waiting times or make queues more enjoyable.

The proposal to achieve them consists of a plan that follows several steps. The plan begins with the implementation of a queuing model that can predict waiting times so that it's possible to analyze and understand the behavior of the queue. The model is M/M/1 and is programmed using Python. It simulates a queue with Poisson arrivals and exponential service times [2]. Once the model is implemented, we are able to identify areas of improvement in the queue, this allows us to reduce wait times and, therefore, optimize processes.

The next step is to design a queue management system using SimPy. This simulation library is really useful for simulating real-life events in Python. It can easily model active components such as customers and servers, which are required in this project. There is a lot of projects that use this library, some of them being related to queueing theory and queueing systems [3]. The system we create in the project using SimPy can control queues, managing the flow of customers based on the behavior of each queue and their real-time status.

Additionally, the system can be monitored through real-time dashboards created with PowerBI [4]. This dashboard consists of a first page where the length of each attraction at that moment is displayed. This value is shown using a color gradient that goes from green to red depending on the length of each queue. It is also possible to obtain more information from any attraction by clicking on it in the previous page. This leads to another page in the dashboard where KPIs such as real-time queue lengths and wait-times are displayed in order to better understand the real-time status of each queue. Furthermore, notifications and alerts are also sent to staff when queue lengths exceed a limit previously defined.

3 State of the Art

At present, companies from all kinds of sectors have already designed queuing models and queue management systems. Their objective is to optimize their businesses, and queuing theory can contribute to it because it can provide shorter waiting times, that lead to a higher customer satisfaction.

Queuing theory has been studied throughout the last few years, which has contributed to the creation of diverse technologies used to optimize queues. These first technologies date back to the 1970s, where physical and electronic methods such as barriers and tickets were first developed. Later on, big industries like healthcare and retail began using these technologies, which lead to an improvement in queuing management systems by implementing real-time data and customer feedback tools.

Today, queue management systems are used in mobile apps, virtual queues, and even contactless payments. They are also starting to implement machine learning algorithms to predict customer behaviour and future long waiting times [5].

In recent years, there has been significant research on queueing models in amusement parks, with the aim of improving queue management and enhancing visitor experience. This specially includes models such as M/M/1 and M/M/k, to predict queue performance based on different factors, like ride capacity, arrival rates, and service times. Research has also focused on the use of simulation and analytical models to evaluate the effectiveness of different strategies for improving queue performance, such as single-rider lines, virtual queues, and express passes [6]. Machine learning and artificial intelligence are also emerging as a promising approach in the entertainment industry.

However, there are still challenges in applying queuing models to amusement parks, such as the dynamic nature of the park environment, the complexity of its queue behaviour, and the variability of demand. Therefore, more research in this field is required to further develop and optimise queueing models in this sector, with the ultimate goal of giving visitors a better experience and increasing the park's income.

As new technologies emerge, queuing theory will become more and more valuable. One technology that can benefit from queuing models and simulations is self-driving vehicles. With autonomous cars becoming more and more common, queuing models can be used to optimize traffic flow and minimize waits during congestions. Additionally, going further, in a future world where all vehicles are autonomous, queuing models could completely get rid of congestions.

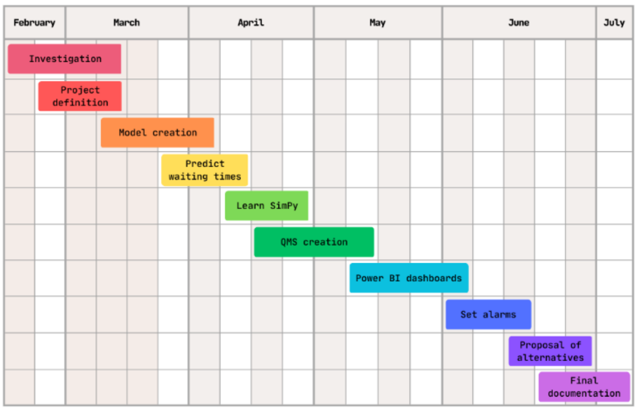
4 Methodology and Planning

The methodology used to complete this project is based in the Scrum framework. As only one person is actively involved in the project, this framework has been adapted to suit the needs [7].

In the project, the Scrum responsibilities of product owner, scrum master and development team are slightly modified so that they can all be assigned to a single person.

The agile methodology used is based in sprints. In the longer tasks there have been more than one sprint and they have been divided on smaller parts of the task. The sprints have lasted between one week and two, depending on the complexity of each task. In addition, there have been weekly meetings with the project tutor. The tasks planning is shown in table 1.

TABLE 1: Planning of the project



As there's only one actively involved person in this project, no planning, tracking or control tools have been used. On the other hand, Microsoft Teams [8] and Outlook have been used as communication tools with the project tutor, although there have also been in-person meetings.

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