A Queue management system with photo recognition to estimate wait time

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Abstract

Queueing is an unavoidable part of life from waiting in line at theme parks or a shop to waiting for urgent care at hospitals, where queue management can mean life or death. Businesses have often turned to queueing theory to optimize operations and ensure that they are able to give the best customer experience. This dissertation will research and investigate how neural networks and facial recognition can be integrated into queueing theory to be able to provide customers with an accurate queueing time. The project aims to identify customers as they enter the queue and track there exit, allowing for the total queue time to be calculated. This information would then allow businesses to provide it to customers allowing them to make an informed decision on whether they wish to join the queue. Furthermore, the system will be able to offer businesses insights into the current customer experience by showing them historical data on queue times and how their demand fluctuates throughout the day. In addition, the project will investigate the ethical considerations and practicality's of developing this set up for businesses.

Contents

1.0 Introduction

1.1 Description of the Work / Project:

Queuing is an ingrained part of everyday life with British people spending over a fortnight a year in queues [1]. In this project I intend to create and research a program for businesses to use which will assist them in calculating the amount of time customers are queuing for their services. This will help customers make informed decisions on how to improve operations. The program being created will work for First come First served queues, a type of queue which is detailed in Queueing Theory which I will discuss later in this dissertation. The program will allow the businesses to look at historic data in the number of times clients wait for a service. This data will allow them to view the busiest points in the service.

This project aims to investigate the use of neural networks with photo recognition capabilities to be able to determine the current wait times in a queue. This will work by firstly identifying people entering the queues and then taking photos of their faces, these photos would be then stored in the system. Once they reached the end of the queue the neural network would then use facial recognition to analyse the photos already taken with the live camera feed. If it makes a match the system would delete the original photo and make a record of how long that person has waited in the queue. This data can then be used to create an average of how long people have waited in a set amount of time given an accurate queue time to new people joining the queue. The system would also allow for businesses to look at historic data to be able to evaluate how long people have waited in the past and make predictions on future demand. The project would have wide use in shops, banks, and theme parks to be able to increase customer satisfaction and give the abilities for companies to have data to improve upon and understand when to allocate extra resources. The project will investigate the effectiveness of the photo recognition system, assessing its accuracy and reliability in estimating queue times.

1.2 Background

The wait times of queues can have huge impacts on businesses, as If they are too long a customer may choose to go elsewhere, or if they do choose to join it could set the reputation of the business to the customer before they have even been able to use their service. A study by Smart Karrot showed that 89% of companies are primarily competing on customer experience, with it being an essential factor for a business to grow in every industry [2]. According to Adobe, focusing on customer experience will lead to 1.7x higher customer retention and a 1.9x return on spend, with the queue being the first interaction with the customer it shows the importance of setting a good impression and how important it is to businesses to invest in [3].

Asides from the effects that a poorly managed queue has on customers, not monitoring queues can have a big impact on businesses. Businesses end up spending at least £28,000 on wasted time, with 48% of employees wasting up to three hours a day [4]. With a proper queue management system, business would be able to view the busiest times of the day and ensure that they are correctly allocating resources at points when its needed most. An improved efficiency would also lead to an increase in sales as a business would be able to increase the amount of people served per hour if they could improve business operations from queue data.

1.3 Problem Statement

Existing queue time estimation methods suffer from significant limitations. The current methods such as manual tracking [5], is error-prone leading to inaccurate data and also hinders the resource management of the business as they require a dedicated staff to monitor the queues. Another current form is using systems such as RFID, although accurate and automated, it can negatively impact a customer's experience as they would be required to carry some form of RFID tag for the system to work, it is also significantly more costly to implement a system such as that [6]. This highlights the need for a new innovative system which is more cost efficient, easy to set-up and does not impact a customer's experience with a business.

This research will investigate the development of an automated queue time estimation system which will utilize neural networks with facial recognition. The focus will be evaluating the programs feasibility, accuracy and most important the practicality of developing the system for a wide scope of businesses to use with minimal setup. The system has the potential to lead to an improved resource allocation for businesses who may look at historic data but also provide customers with an enhanced experience, both providing customers and businesses with rich data-driven insights.

1.4 Aims And Objectives:

The aims and objectives of the project are:

1. In this project I am to research Neural Networks to be able to investigate their effectiveness in being able to provide businesses with vital data on queues within the business.

    a. Explore what neural networks are and which particular type of neural network will best suit this project
    b. Exploring how previous solutions are not as effective as Neural Networks.

2. I aim to research a version of the software used to estimate the queue times to be able to demonstrate the concept and be able to aid in concluding on its effectiveness within businesses. I will demo this software at the end of the project's development.

    a. The solution must be as effective as previous methods of calculating queue time to be able to replace previous methods.
    b. The software must record information for businesses to look back on to learn from historical data.
    c. To be developed in Python with easy-to-understand code for businesses to be able to implement them without much setup.
    d. Create a system to work for First come First served queues (as detailed in Queueing Theory) and evaluate the systems effectiveness in other forms of queues.

3. I aim to conduct an ethical assessment on the final concept of the software and evaluate on the ethical considerations a business would need to consider before implementing the software in everyday use. I also aim to make a review on the accuracy of the software and whether it's an improvement on current methods of measuring the queue wait time.

    a. The created solution must delete any photographs of people it takes to ensure data of people are not being kept which could put them at risk.

2.0 Literature Review

2.1 Previous Work

Queueing management has and always will be a big focal point within business over many industries, it has always been a challenge for businesses to optimise customer wait times and maintain an operational efficiency. This review aims to explore the existing solutions around tracking queue times and queue management, while exploring queue theory and how this data can be processed. By exploring current queue tracking systems, this review will then explore the need for a new innovative solution using facial recognition to improve upon current solution.

There is already a plethora of work surrounding facial recognition, however its ability to be used within queueing systems remains relatively limited. One notable study comes from “"Waiting-Time Estimation in Bank Customer Queues using RPROP Neural Networks” which uses neural networks to estimate wait times in a queue at a bank from an algorithm called “Resilient Backpropagation” [7]. The study focuses on predicting the wait times based on customer arrival patterns, the service times and current queue lengths. Their aim was to improve the efficiency and accuracy of queue management systems in service industries. Another example of this is found in “Face recognition in an unconstrained environment for monitoring student attendance” by Justin Worsey which explored the use of facial recognition to track attendance to lectures [8]. Although it is not directly tracking queue times such as this project, it however highlights the potential for facial recognition being used in an uncontrolled busy environment.

An important aspect of looking into new ways to manage queue times, is to look at pre-existing methods and evaluating their limitations. Although these methods are widely used and implemented into various industries, they often lack the adaptability and efficiency that a modern system could potentially bring. One of the most basic solutions of them all is to manually track the queues, by handing a customer a card that they hold until they reach the end of the queue [5]. At the end of the queue the customer hands the card back in and the time is recorded between those two interactions. However, the accuracy can be compromised if a customer forgets to hand back the ticket or abandons the queue altogether. Also, it makes it more challenging for businesses to maintain accurate date over extended periods of time which could of benefited them in understanding when they need to allocate more resources.

In contrast, another method is to use RFID (Radio Frequency Identification) for queue management, which is increasingly being adopted particularly by companies such as Walt Disney World [6]. The system utilises RFID chips which are baked into the customers entrance cards or wristbands to monitor queue times. Customers must walk through a specialised entrance or exit barrier which captures their ID at each end and calculates the time. The technology offers significant advantages over a manual method by providing more accurate data with minimal user input to make the system work. However, the system does have some substantial downsides with one being the infrastructure cost. To make the system work the businesses needs to install entrance and exit gates to each of it queues and ensures that each customer has an RFID card in their pocket which makes it practically impossible for some business to use this if their customer is unlikely to carry one of their cards. Having the additional setup could also raise maintenance costs and give more room for error due to the scale of it. This makes it particularly difficult for small businesses to make use of these systems.

2.2 Under Researched Areas:

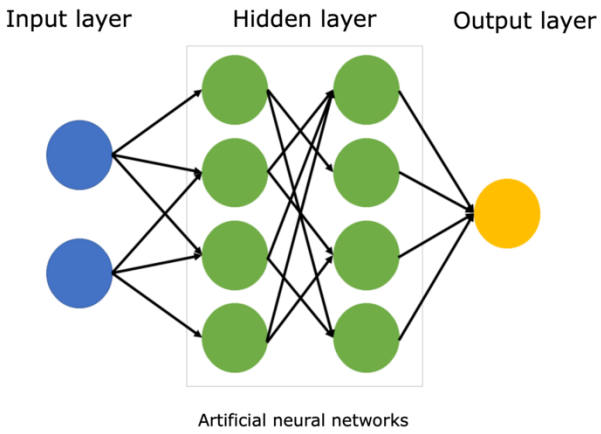
While there has been some research into how facial recognition can be used to monitor queue lengths, studies are relatively limited with there being a lack of research exploring its practical implementations and limititations. This project aims to investigate developing a system capable of replacing current world applications and then explore the limitations of it.

2.3 Neural Networks

A neural network is built upon lots of interconnected nodes, a system which design was inspired by the human brain. It takes in many inputs and turns it into the desired output using complex weighted layers of calculations. Inputs enter the network and get directed into the input layer, depending on the learning process and strength association, a part of the input will fan out into the next layer. This process is seen all the way through to an output, which the result will be a modified version of the original input such as a result or classification [9].

For a neural network to work it first must go through supervised learning [10]. This is when the output is labelled, or training data is available, so the network can learn how to produce the output. Supervised learning in a fundamental role in training the neural network. This involves providing the network with a sample of labelled examples, in this case of this project it would be a set of faces, so it learned how to recognise a human face. This would then help it to learn and adjust the parameters to generate the desired output. The more supervised learning that is done for a neural network and the greater number of examples provided will increase the networks accuracy. The network will continuously refine itself by comparing its outputs with the desired outputs by altering its calculations, this enhances its ability to provide accurate results. For neural networks to work for facial recognition, we need to ensure that a wide dataset is provided to the database and to ensure that all genders and ethnics are represented within the data. This is required because not providing a proper dataset could cause the neural network to become biased and only able to recognise some people in the queues [11].

In relation to this project, neural networks will be playing a fundamental role in making the system work within two key areas, Facial Recognition and Queue Time estimation. By using pre-trained data, the network will be able to identify human faces upon entering the queue where it will then take a photo and process them, turning them into a string of code also known as an identifier. Once again enhanced by its initial training, it will then be able to accurately pick up people's faces at the end on the queue and identify if any of them match the original identifier. Furthermore, harnessing neural networks can help make the queue time estimation even more accurate as neural networks can analyse complex patterns and relationships within databases. This is an advantage to businesses as it would be able to continue giving accurate wait times even when the queues are having influxes of demand.



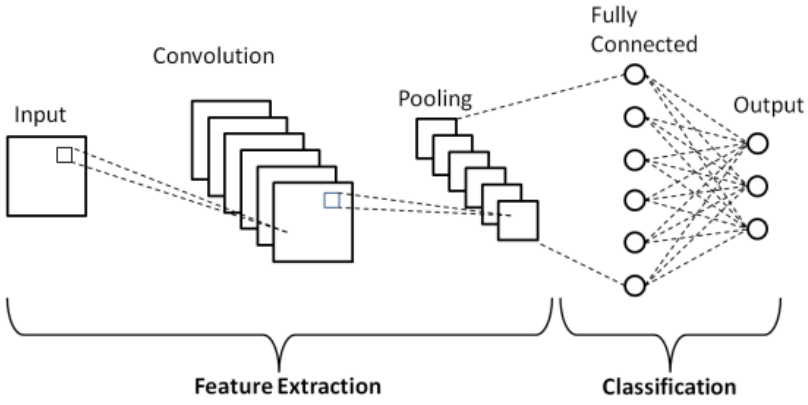
Artificial neural networks

This diagram [2.1] shows a very simplified version of a neural network. It shows the three important layers of the network. The input layer which receives the input. Then the hidden layer which is where most of the computation happens. The hidden layer can be built upon many different weights which effect the output. And then the output layer which is the final output of the network. Neural networks are very versatile, and this diagram only represents a very simplified version.

2.4 Convolutional Neural Networks

Convolutional Neural Networks (CNN's) are a form of neural network that is primarily used to handle and classify images, it's a significant advancement in deep learning essentially giving computers vision. These forms of neural networks are advanced in image processing and classification tasks which completely changes how computers can interpret visual data.

Key to the CNN is the convolutional layer, this is an important part of the network which is responsible for data processing. Within this layer is a set of filters, also known as kernels, these are systematically learned during the training process. These filters are important to be able to extract features from pictures or a live feed, effectively these detect patterns and spatial relationships within the images. By using the learning process, CNNs can increase the accuracy and fine tune the filters to increase the facial recognition features which optimises the networks accuracy but also the performance of the system. A particularly important node in CNNs for this project is the Local Connectivity. What this means is that the CNN will analyse image regions in relation to the surroundings, this is crucial in busy queues as it allows it to focus on the important facial structure details to be able to recognise faces, even if the faces may be partially obscured or captured at slightly different angles [12].



Above shows a diagram [2.2] of how a Convolutional Neural Network is formed. As shown, it starts with an input, sends to the convolutional layer which applies the filters to the image (producing feature map) and then sends to pooling which reduces dimensionality of the feature map which reduces computational cost and then sends to the fully connected layer. The layer is an artificial neural network that performs the actual classification on the image [13].

2.5 Facial Recognition

Facial recognition is one of the biggest uses in computer vision technology. This is a form of technology which is designed to identify individuals and recognise them based on previous recognition. Facial recognition algorithms rely on complex mathematical models which looks at the patterns of faces, such as distance between key features on the face, to be able to assign it a unique identifier which it can use for future recognition.

It first begins with being able to identify faces, the algorithm will scan a digital image or a live feed and locate areas of the image which may contain a face. It's able to do this from the training stage of the neural network where the computer is trained in what a human face looks like from a large dataset. Once it has identified a face, the computer will extract important information that is unique such as the size of eyes or mouth for example. It will also measure the distance between these features and look for any other distinctive characteristics. The more training the facial recognition model had, the faster and more accurate it is at being able to identify a face. The conversion process in facial recognition encodes the facial landmarks into a numerical value which is also known as a feature vector btu acts as a unique identifier for the face its identified.

Similarly to when facial recognition is identifying faces, it looks out for faces within the pictures frame, and once again starts working out the feature vector for people it finds. However, on this occasion, its able to match previously recognised feature vectors to faces its recognising within the moment to be able to identify who it is looking at. This capability gives computers ability to use facial recognition as a biometric authentication or for a project such as this one, which will use it to identify people at the start and end of a queue [14]. Facial recognition doesn't just stop as being used as a biometric, it has been proven to be an asset to many industries even within government. Most recently, the Chinese government have implemented facial recognition algorithms to identify criminals within public CCTV cameras which shows just how versatile this technology is [15].

2.6 Queueing Theory

Queueing theory, being originally proposed by Whitt in 1999 [16], is the mathematical model created to analysing wait times. The queueing process, as outlined in queueing theory, is the population of potential customers, the input / arrival process of customers, the service process, and the number of parallel servers. It is crucial for my project to include queueing theory as it provides an analytical framework for understanding calculating wait times in queues. The theory focuses on mathematical models to analyse elements such as customer arrival rates, service times and queue pull techniques [17].

While queueing theory was originally created to be able to analyse computer systems it's still a very useful tool which can be applied to a wide range of queues in real life to help businesses evaluate their performance and build tools such as this project to be able to monitor queue time. Queueing theory is an important concept to incorporate into my project because accuracy is important with it being a data-oriented program. By using this theory, it will make sure that the estimated wait times are accurate and allow the system to analyse historical data which is beneficial to the businesses.

2.7 Queuing Types

Depending on the type of queue, which is in operation within a business, depends on how the customers get served, more specifically it details the order in which they will get served [18].

First in first out – This is the traditional method of queueing where the first one into the queue is the first one to be served. An example of this is often seen in supermarket / bank queues or theme park queues.

Last in first out – This is the opposite of FIFO, where the last person to enter the queue is the first person to be served. An example of this would be a lift / elevator where the last people to enter are the first people to leave.

Shortest job first - Where the customer with the smallest job is served first. An example would be how in a takeaway people with bigger orders will be waiting longer.

Priority – This is where the customers with the highest priority will be served first. An example of this would be in a hospital.

2.8 Kendall's Notation

A standardised way to be able to describe queueing systems would be to look at Kendall's Notation [19] which is particularly popular in queueing theory. Kendall's notation was created by David George Kendall in 1953 and has since been used to classify queueing nodes. It's a classification system which is used to represent queues in a compact way using an A/B/C form with the letters representing the queue in terms of its time of arrival distribution, service time distribution and number of servers.

Kendall's Notation is (a/b/c) and then was further extended to (a/b/c) : (d/e)

Where:
A = The Arrival pattern to the queue
B = Queue System Service Pattern
C = Queue Service channels
D = Queue Capacity
E = Queue Discipline

The diagram above shows a M/M/1 queue as found in Kendall's notation. With the M meaning Markovian which is a statistical property, the first M is the inter-arrival time which means time between arrivals follows the exponential distribution with parameter λ. The second M is the service time of customers being served with parameter μ. Finally, the 1 is showing there's only one service channel, which would mean only one can be served at any point. It is a crucial concept for the project as it represents a standardised way to describe and analyse the system. It also provides a foundation for being able to analyse the performance

3.0 System Requirements

Below I shall outline a set of requirements that I am aiming for my program to achieve

3.1 Facial recognition

- The system to be capable of detecting and recognising faces within the camera feed
- The system should identify individuals and maintain a record of their entry and exit in the form of time stamps.

3.2 Queue Time Estimation

- System should be able to estimate the wait time for everyone based on entry and exit times.
- The system should be able to provide real time updates on the queue length.

3.3 Accuracy

- Facial recognition should achieve high level of accuracy to recognise individuals.
- The queue time estimate should provide an accurate queue time.

3.4 Usability

- The system should be clear and user-friendly to set up, allowing even small businesses to make use of the project
- Information should be written to the JSON in a clear and easy to read for manual inspection of the document.

4.0 The proposed queue system

The following section details the technical work, research and demonstrate for the concept of using facial recognition to estimate queue times. The order is written in the order of which the program is used. Part of this chapter will specify the proposed queue monitoring system using facial recognition. It will incorporate elements of queue theory into its design and employ neural networks to be able to recognise customers faces to be able to track them through the queue. Furthermore, I will then discuss how this can be applied to small businesses and what the advantage to using this system will be over the current systems that are available. I will then evaluate what may be some of the limitations of having this system in use.

4.1 Chosen Technologies

For this project I will be creating the program in Python, this is because python already has extensive libraries for neural networks making it a natural choice. Being a very popular language in the industry [20] , it ensures the program is more accessible and easier for others to use. Python is also a programming language that I am very familiar with which will help with development of the solution.

4.2 OpenCV Library

For this project I have decided to use the OpenCV library which is an open-source library that features machine learning and computer vision tools. The reason I have chosen to use this library is due to it being around since 1999 and has been updated and developed by a large community meaning there is a lot of documentation available. OpenCV is natively used for C++ with python being the wrapper however it ensures that python can use OpenCV very easily. By using an optimal library such as OpenCV, it will help speed up the development process of the application [21].

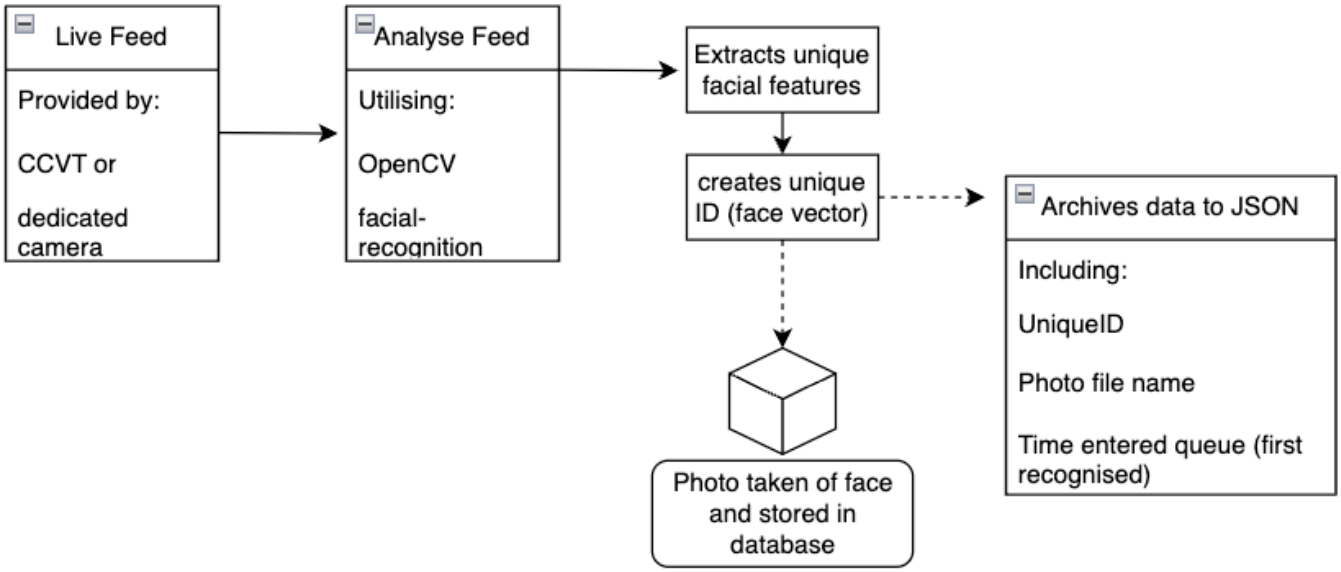
4.3 Facial-recognition Library

To have face detection, this project will be using the facial-recognition library for python [22]. The library uses pre-trained deep learning modules to detect faces from the live view camera but also the images that will be stored of customers waiting in queues. When the library detects a facial structure, based on the pre-trained modules, it will turn it into a numerical representation known as a face embedding which notes all the facial characteristics of the person. This encoding is what helps the system to differentiate between different people which allows it to recognise faces. A key mechanism in making the library work, is its ability to use distance metrics to read faces, The facial-recognition library is built upon deep learning. Deep learning is based on a basic concept of neural networks, requiring a training phase to learn how to see faces. However, the facial-recognition model implementation is available in the OpenCV library, which has a model already trained to recognize faces. This will make the set-up process significantly quicker for the project, however it will sacrifice the ability to control the amount of training the initial model has which could have an impact on accuracy and recognition speed.

4.4 Queue Entry – First Stage:

The very first stage of the system utilizes a live feed provided by a camera at the start of the queue, this is very versatile for businesses as they could harness a CCTV camera. OpenCV and face_recognition libraires are then used to analyse the feed in real time utilizing deep learning techniques to recognize faces in frame and conduct several processes for later use within the system. The very first of these processes is to extract unique facial features which it can then use to generate a unique face encoding, meaning it can then recognise those faces again. It does this by measuring the distance between certain facial features. The encodings are unique to everyone which is what helps the system to distinguish between different people and even in a busy queue it will still be remarkably accurate.

Once the face has been recognized and encoded the system then starts actions to document the person. Firstly, a random eight-digit number is assigned to the person to act as the unique identifier which ensures the system can track the user through the whole process. Meanwhile, the system will also take a photo and archives the persons face into the system, this will be used at the end of the queueing process. Once these two processes have happened the system them makes the most crucial step which is documenting the persons unique ID, photo file name and the time that they have entered the queue into a JSON file. This documentation is fundamental for the system as it helps keep track of the people in the queue and the times which they enter and leave.



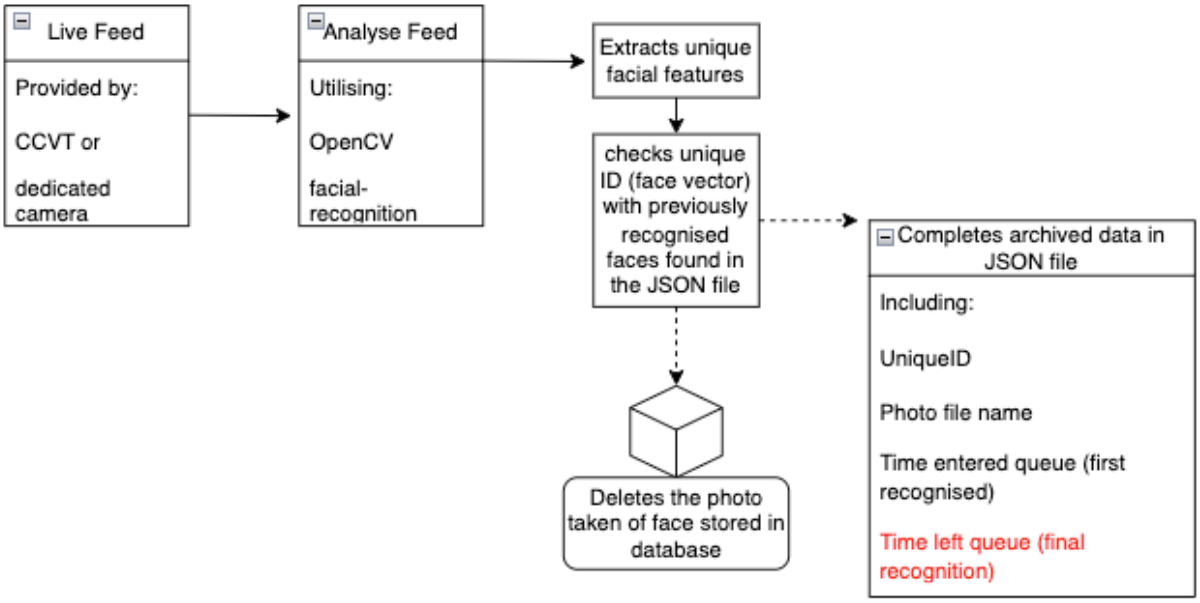
Above shows a diagram of the processes which are conducted at the very start of the queue. It details the image first being captured by the live feed, analysed, and then extracted for facial features, getting a unique ID. It then shows a photo being taken of the user and stored in a database, with key information such as the time they entered the queue being stored in a file for future use within the system.

As can be seen in the image above, this software is demonstrating the first stage of the project. The red boxes are showing that the software is currently processing the persons face, by taking a photo and documenting them in the JSON file. The green boxes are showing those who have been successfully processed. As the queue moves forwards the software will be constantly processing new people.

4.5 Queue Exit

The next part of the system involves processing customers as they reach the end and exit the queue. This stage operates in a very similar way to the initial phase, utilizing the same libraries for face detection and recognition. However, it is important to note that the camera in this phase must be independent, ensuring that it does not capture the front of the queue or any frame matching that captured by the first stages camera. This precaution is essential to prevent any inaccuracies in the data such as processing individuals who have just entered the queue as this would signal them immediately being at the exit.

During this stage, the system still continuously monitors a live feed and monitors the faces entering its field of view. When it detects a face, it compares the face encodings to those that have been captured earlier on. It's able to do this from the photos that were initially taken of everyone when they entered. As soon as a match is found, the system will promptly delete the photo from the system. This deletion not only ensures the safety of the customers data, but it also ensures the future accuracy of the system in-case the customer was to queue again later. The system will then update the JSON file with a new timestamp showing the time of queue completion, its able to find the customer on the file from their unique identifier assigned earlier. Once this process is completed, the system is no longer able to recognize the customers face, effectively removing them from the system and concluding their queue time.



Above shows a diagram of the processes which are conducted at the very end of the queue system. Additionally, from the previous diagram, the system is now checking the unique ID's against previously recognised faces. If it finds a match it deletes the photo from the database and then adds in the additional information of when the user has left the queue to the JSON file.


```
{
    "people": [
        {
            "id": "98325127",
            "filename": "unknown_98325127.jpg",
            "name": "Person_98325127",
            "timestamp": "2024-04-18 22:33:33",
            "queueTime": "2024-04-19 00:26:14"
        },
        {
            "id": "24314049",
            "filename": "unknown_24314049.jpg",
            "name": "Person_24314049",
            "timestamp": "2024-04-24 00:32:08",
            "queueTime": "2024-04-24 00:41:33"
        },
        {
            "id": "66099723",
            "filename": "unknown_66099723.jpg",
            "name": "Person_66099723",
            "timestamp": "2024-04-24 00:32:10",
            "queueTime": "2024-04-24 00:37:50"
        },
        {
            "id": "36193589",
            "filename": "unknown_36193589.jpg",
            "name": "Person_36193589",
            "timestamp": "2024-04-24 00:32:11",
            "queueTime": "2024-04-24 00:41:32"
        }
    ]
}
```


Above is an example of the JSON file which gets created at the start of the queue and filled with timestamps at the end of the process. This is then what is used in the system to calculate the final wait time and allow it to look at historic trends in the data. As shown, this holds the timestamps of entry and exit to the queue and the unique ID that the system gave to the person. It also includes the name of the photo taken of the user to ensure data can easily be tracked in the system.

4.6 Queue Time Calculation

In the current demonstration of the software, a very simple program will iterate through the last five processed individuals. It takes the time that they entered and exited the queue and works out based on those five individuals the average wait time. However, this is significantly inaccurate and not a suitable way to calculate queue time. This is because the business may not have anyone enter the queue for several hours, but the data will still be showing the wait time from when the last person entered the queue. A simplistic fix to this problem would be to only inspect the last 5 people who entered the queue but within a given timeframe, such as an hour. This however, will still lead to inaccuracies in the data as customer flow may be very varied and inconsistent within that hour.

A significantly better approach to this problem would be to integrate neural networks into calculating the queue time. This is significantly better as neural networks have great ability to learn from complex patters of data. The system would need to be trained on historical queue data, and then the neural network can then search for underlying patters in customer behaviour and queue dynamics which will then be able to create much more accurate predictions on what the current queue time would be.

By studying Kendall's notation and implementing its theories into neural networks it will be able to significantly enhance its capability to model and predict the queue behaviour even more accurately. The system would use M/M/1 queueing model alongside the neural network, which would help gain the deeper understanding of customer arrival rates, service times and the queue lengths which would make the overall result more accurate.

4.7 Business Analytics

The final function of the software it to be able to utilize the historic data that gets stored in the JSON file when customers enter and leave the queue. This historic data which includes the date and time of their queue entry and exit can be utilized for businesses to gain insights into their customer traffic patterns. This data enables them to make informed decisions on how to utilize resources such as staff by being able to monitor trends in customer footfall. Additionally, once data has accumulated over several months, they will be able to see trends in the seasons allowing for better future planning. The integration of being able to look at the analytics of the system will help the business enhance operations and become more efficient thus leading to a superior customer experience no matter the industry.

4.8 Chosen Queue Methodology

The current implementation that I have produced is based on First-In, First-out queue theory methodology [18]. This is where the first person to enter the queue is the first person to be served. The reasoning behind choosing this particular methodology is due to it being the most common type of queue. By developing the system for a first in first out queue, it can deliver the most balanced approach and ensure a fair and predictable experience for real life queues which makes it ideal for a quick setup for small businesses.

Although possible, other types of queues such as a priority queue as used in hospitals, may not be ideal for this specific iteration of the application. This is because to service other forms of queues it would require the system to assign subjective urgency values to individuals which would be particularly difficult for a computer to know without any human input. If human input was needed to share data with the computer on how urgent a customer was to then be able to calculate the wait time it would defeat the objective of the facial recognition. It would also make it a much greater scale if used within a hospital as the system is designed for a definitive end point, whereas in a hospital customers could be sent to various locations each with different queue times.

4.9 Information Delivery

An important aspect of the system is being able to deliver customers the queue time information. Although a versatile system is important and displaying the live queue time directly on the system to provide businesses with the option of displaying it directly on a monitor, a more professional solution is needed. The ideal solution to be able to achieve this would be using API's to directly deliver the live queue time to the business's website or even on a wireless display at the front of the queue.

Depending on the scale of the businesses, they may choose to go with an API option to deliver the information to the customer. Application Programming Interface (api) are a way for programs to communicate with each other or with other components. This is useful in displaying queue times as it provides a clean method to get the data from the system and provide it in various ways to the customer such as on a website, mobile app or even sent directly to a screen at the start of the queue. Businesses such as Alton Towers have been utilising API's for many years in order to get the wait times from a central server across many service access points across their site.

5.0 Testing and Evaluation

The following section evaluated the proposed method and my aims and objectives of the project.

5.1 Testing

Testing of the initial demonstration code is fundamental to be able to access its use in real life scenarios. The code is made up of three separate scripts, which are each responsible for specific functionalities within the program. This allows each component to be tested individually. To test the programs performance, I will set predefined parameters and then test how the program responds to them. To simulate a queue, I will hold up photographs of people within a queue environment to the program. This allows a more controlled testing environment and helps to assess the program in many conditions.

Action	Result	Comment
Light queue – A picture in perfect conditions of a queue containing less than 5 people will be held up to the program's camera. Both the start and end queue points will be tested, ensuring full processing of the people in the picture. Tests will be successful if the program fully process everyone. Speed will also be tested.	The program recognised everyone in less than 10 seconds. Everyone was processed correctly by the system	Test was successful
Busy queue – a picture in perfect conditions with a queue of 10 or more people. Testing both start and end queue for successful processing and speed.	Although the program did identify and recognise everyone that was in the frame, its processing speed was massively impacted. It took about 30 seconds for everyone within the cameras frame to be recognised.	Test results were not as expected, significant speed issues.
Poor conditions – A picture of an outdoor queue in poor conditions such as in rain or storms. Only the start point will be tested, to see if the program can pick up the individuals.	Due to people in the picture wearing coat hoods the software failed to pick up any faces.	Test failed
JSON file check – check to validate that the information between stages is being saved correctly	A visual check between each stage was ran showed that the JSON file was being correctly updated with the queue entry and exit times.	Test was successful

Running the final stage, to get the average wait time	Although the system was able to give an average queue time, it did not account for any abnormalities in the data and would still display a long wait time, even if that rush of people had come in an hour ago and the queue was now empty.	Test successful but requires improvements

Testing has proven that although the system does function as intended, there are many improvements that could be made. During testing it was notable that the system gradually slowed down as more individuals appeared in frame which caused it to take longer to process individuals. While this slowdown does not pose a significant issue to the overall functions of the software, as the system can still calculate an average wait time based on the people it does process, it raises concerns on the systems scalability especially in businesses with larger crowds. Testing was conducted on a personal laptop, which I believe will have had a significant effect on the time it took to process everyone. For this reason, I have concluded that on large scale set-ups the software would need to be ran on a significantly more powerful computer. The system also failed tests in images of outdoor queues when weather was causing individuals to cover their faces. This issue is unavoidable for this solution on outdoor queues.

5.2 Identification of potential problem areas

One potential issue with the current implementation is if the customer is not captured at the other end of the queue. For example, if the customer was to go on a theme park ride and their face was to be captured as they initially went through the queue but then reached the end and there face was blocked, which would mean that there final reading was not captured. If then the customer went on the ride again the first camera would not capture them again and the second camera would act like they never left the queue which would then give the time it took for them to do two rides making the total queue time inaccurate. A simple solution would be to adapt the end of queue program so that it monitored and disregarded any obscure results, alternatively the

As we have currently witnessed in the 2020 COVID pandemic, facial recognition systems can be made redundant overnight with face coverings impacting on the software's ability to recognise faces [24]. With the proposed system in place, it would be completely unable to perform its task if the people in queues were wearing masks. Similarly, if it was an outdoor queue and people used hoods or umbrellas it would also impact on the software's ability to pick up faces and make it completely useless. However, if paired with the card method of tracking queues for situations such as those, part of the system could allow for manual inputting of data so that future data is not disrupted.

From initial tests some photos that get taken at the very start of the queue are not fit for purpose and may have been taken by accident such as a gust of wind blowing someone's hair to stop there face from being viewed just as the photo is being taken, although rare this does cause there to be a backlog of photos which do not get deleted at the end of the day. To solve this issue, I developed the system further so that when the system detects the photo has been taken over 12 hours ago it will automatically be deleted. This amount of time can be changed by the business to prevent it from deleting photos in situations where they are wanting to track people for more than the set time in a queue.

5.3 Data Storage Evaluation

As previously discussed, my project has made use out of a JSON file to store data that the camera captures such as when the face was first captured, when it was recognised and the time they spent in the queue. Storing the data directly to a JSON file was decided over a traditional database system due to its lightweight nature, it allows people to easily read the data directly from the file. As JSON is a much lighter way of storing data, it better suits the program as in busy queues it could be recording a lot of people at one moment, this should ensure processing speeds are not affected. A downside of using a simple JSON file could become apparent after the system is used in busy queues over a much longer period, this is because the JSON file may reach its size limit or start to experience performance issues which would slow the entire system down. If the ever-increasing size of the JSON file started to hinder the system, the files could start to be achieved by day within the structure of the system. Archiving would reduce the size of the individual files and make it easier to manually view the data.

However, the JSON file only stores the text data from the program and not any photos of the people in the queue. The photos of the faces are stored directly to a 'Faces' folder within the program. This gives a few key advantages with it potentially having faster access times when retrieving the photos for smaller businesses such as banks and shops. It also makes the system simpler to set up, which is one of the aims of the project to ensure that the system is simpler than current solutions. As the photos get deleted as soon as they are matched with someone it wouldn't require much management from smaller businesses. This could cause some issues in significantly larger queues (such as those entering large festivals or concerts) as having several thousand faces stored could start to slow down the system. It also threatens the data integrity if the businesses choses to implement the system on an online system as there's no mechanisms to ensure this in a folder structure and no way to go and track any changes made to the photo or attributes.

5.4 Ethical Considerations

Facial recognition is becoming much more common in daily life, even down to logging into people's phones. However, this does not make it any less important to address the significant ethical considerations in capturing people's facial biometric data when the public may not be aware that this is happening. People remain very uncertain and uninformed about how the facial recognition systems can work due to lack of transparency which does end up raising concerns about privacy. The proposed system addresses the ethical and privacy considerations by minimising the amount of data that is taken from people. As soon as the customer has entered the queue, an image of them is captured and stored onto the system for later recognition. The system ensures that the photo is only stored for this purpose, once a customer goes to exit the queue it will automatically wipe the photo from the system making sure that the personal data is not stored for any longer than needed. However, an issue with this system would be if the camera failed to recognise the person at the exit of the queue, the photo would fail to be deleted. This is why contingencies should have been added to the software to ensure that any photos taken from the previous day get deleted automatically.

Another aspect of data is those that's stored onto the JSON file once a customer has been recognised. Ethical considerations have been made here and no personal data would ever get stored onto the system. Instead, users are allocated with a unique ID number instead of using their names. Once the original photo of the customer has been deleted, it is no longer possible to figure out who the customer was from the JSON file as all it shows is a unique ID. Ensuring that privacy is implemented into the software straight away will help companies be more forward into using the software as customers will feel there data is secure and being used for the sole purpose of queue tracking. [23]

5.5 Implications for Businesses:

After researching the feasibility of a queue tracking software, it has become clear that the biggest benefiters would be small businesses. To implement the system would be relatively small costs, due to it being able to harness pre-existing CCTV cameras and not require frequent maintenance. Many small businesses do not currently have such a technology installed as pre-existing methods are costly or too labour intensive, this system would allow them to gain the technology without any implications. Customers will benefit from the transparent queue lengths before joining, as it will manage their expectations and remove any frustration as they know the length of the queue before entering. It will also help spread demand for businesses throughout the day instead of just having rushes of customers, this is because customers will be able to see when the quietest point is to visit and may only visit during that period. The data insights generated by the system offer very valuable advantages to businesses. A business will be able to identify the peak periods and manage the resources to handle them, ensuring that resources are not wasted at points that historical data shows its quiet.

5.6 Algorithmic Bias

Although this project and many others that make use of facial recognition, show how useful the technology can be, it has been recognised recently that many of these systems suffer from algorithmic bias. This happens when the software is discriminating or producing inaccurate results by not being able to recognise everyone that enters its view. It can happen in a couple of different forms such as racial and gender being the top two. This presents a significant challenge for this project if it is not addressed as it would result in the system being unable to recognise everyone that enters the queues. Algorithmic bias occurs when the training data is not varied, and the computer is only being shown one ethnic group or gender. To address this in this project, a varied training data set should have been used. As this project makes use of the facial-recognition library and OpenCV it means the training data has already been provided externally. This puts the project at a significant disadvantage as it is not possible to verify how varied the training data was. Future development should ensure the system is trained internally and that the dataset has been verified to ensure it is varied.

5.7 Evaluating the Aims and Objectives

Overall, I am very happy that I was able to meet the majority of my aims and objectives that I set out before taking on my project. I shall evaluate each one that I had set out.

Firstly, I aimed gain a greater understanding of neural networks. I was successful in researching and understanding how effective neural networks can be and the best type for this project, being convolutional neural networks. I was also able to explore how neural networks were significantly more superior over traditional methods using in tracking queues.

Secondly, I was successful in creating a demonstration of my project which was as effective as previously existing methods, but more accessible to smaller businesses. The system recorded historical data and was developed in python for First come First serve queues. However, I was unable to produce a version with a user interface which I feel could have benefited this project to give a greater vision of how the completed project would operate.

My final aim was to ensure that data on the system was handled ethically. I was successful in doing this and keeping in mind people's privacy, ensuring that each photo of individuals entering the queue were deleted once they reached the end. I also ensured that any data recorded for historical purpose used a ID code instead of any personal data from the individual. However, I did not make any function within the code to ensure that the system deleted the photo if the individual was not recognised at the end of the queue.

5.8 Conclusion

Over the course of the project, I have been able to develop my knowledge and understanding of neural networks and facial recognition, including research into different algorithms suitable for the project such as Kendal's Notation. Upon reflection of the final project, I am very pleased I was able to demonstrate an example of how the system would work in real life. However, with better project management I would have wanted to be able to develop a user interface and combine each of the functions together. I also would have preferred the demonstration to calculate the queue time using neural networks. However, I do recognise that I set my self an ambitious task at creating the system.

A new form of queue monitoring system making use of facial recognition is an important advancement compared to current technology. All the systems today either require significant setup, high starting costs or are labour intensive. Implementing this system could benefit businesses no matter the size, but particularly the small businesses with limited resources that may have struggled to have a queue management system without a low-cost solution.

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Diagram References:

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UG Project Plan
CSC-30014

Project Overview and Description

Student Name: Thomas Herward
Student Username: X3D82
Student Number: 20014189
Degree Title: Computer Science single honours
Supervisor Name: Dr Vishwash Batra
Project Title: Queue management system with photo recognition to estimate wait time

Please provide a brief Project Description:

This project aims to investigate the use of neural networks and photo recognition capabilities to be able to determine the current wait times in a queue. This will work by using a randomly selected person on entry to the queue and then waiting until the software recognises them again at the end of the line to work out the queue time, harnessing neural network algorithms. The project would have wide use in shops, banks, and theme parks to be able to increase customer satisfaction and give the abilities for companies to have data to improve upon and understand when to allocate extra resources. The project will investigate the effectiveness of the photo recognition system, assessing its accuracy and reliability in estimating queue times.

What are the aims and objectives of the Project?

In this project I am to research Neural Networks to be able to investigate their effectiveness in being able to provide businesses with vital data on queues within the business.

I aim to create a version of the software used to estimate the queue times to be able to demonstrate the concept and be able to aid in concluding on its effectiveness within businesses. I will demo this software at the end of the projects development.

I aim to conduct an ethical assessment on the final concept of the software and evaluate on the ethical considerations a business would need to consider before implementing the software in everyday use. I also aim to make a review on the accuracy of the software and whether its an improvement on current methods of measuring the queue wait times.

Please provide a brief overview of the key literature related to the Project:

'Queue Time Estimation in Checkout Counters Using Computer Vision and Deep Neural Network by Muhammad Atif Irfan, Muhammad Zohaib, and Muhammad Aamir Shahzad' is a paper that proposes a system for estimating queue time in checkout counters using computer vision and deep neural networks. This system works by detecting and tracking people in the queue, and then using a deep neural network to estimate the time it will take for each person to reach the checkout counter.

'Waiting-Time Estimation in Bank Customer Queues using RPROP Neural Networks by R. K. Jena, S. K. Rath, and R. Panda' is another paper that proposes a system for estimating waiting time in queues, but this time using RPROP neural networks. This system works by collecting data on the number of customers in the queue, the number of servers available, and the average service time. This data is then used to train a neural network to estimate the waiting time for each customer.

'Y'OLO: Real-Time Object Detection with Region Proposal Networks by Joseph Redmon, Santosh Divvala, Ross Girshick, and Ali Farhadi' is a paper that introduces the YOLO algorithm for object detection. YOLO is a fast and accurate object detection algorithm that can be used in real time. This is important for queue time estimation, as it allows us to identify and track customers in a queue in real time.

'A time series forecasting approach for queue wait-time prediction by A. S. Kumar and H. V. P. V. N. Rao' is a paper that proposes a time series forecasting approach for predicting queue wait times. This system works by collecting historical data on queue wait times and then using a time series forecasting model to predict future wait times. This is important for queue time estimation, as it allows us to predict waiting times in advance, so that we can take steps to reduce them if necessary.

'TensorFlow 2: A Practical Guide for Beginners by Anirudh Koul and **Learning PyTorch: A Hands-On Guide for Beginners** by TutorialsPoint' are two books that provide comprehensive introductions to TensorFlow 2 and PyTorch, respectively. TensorFlow 2 and PyTorch are two popular libraries for machine learning and deep learning. They are both well-suited for use in applications such as queue time estimation, where they can be used to train and deploy neural networks.

Project Processes and Methods

Please provide a brief overview of the Methodology to be used in the Project (inc. an overview of best practice within the Methodology):

Within my project I have chosen to go for an Agile methodology which will involve me dividing the project up into smaller, more manageable targets. An Agile Method allows for continuous reviewing and adaptation to ensure that the project will remain on time. However, as I am completing the project by myself and not as part of a team, I will need to ensure that I hold my self-accountable and have discipline to the target. I will set myself realistic goals and ensure I review my progress on a weekly basis and make any required adaptations to ensure I'm on target.

Overall using an Agile methodology will be beneficial in my project and ensure that I'm completing it effectively. It will give me the ability to review my progress and make improvements during the project but also help me stay on track ensuring the project gets completed on time.

Will any special Data Collection Methods will be employed (e.g card sorts, questionnaires, simulations, …)?

I do not plan to use any special data collection methods such as card sorts and questionnaires. I do however plan to simulate my program by using stock images of queues to try and replicate how it would work in a real-life environment. For example holding up a stock image of a person and removing it from the cameras view, brining it back into view should then get amount of time that that photo was away from the camera as the result. It will then later be tested as a photo of a queue of people where the software will have to pick out one person from that group, it will then be tested again after a period to get the required data to show the program is functioning. This method will be ethical as it will be using widely available stock images of people / queues which will have already gone through with asking the people within the photos if they approve it being used. The photos will only be of adults.

Briefly describe how you will ensure your project is in line with BCS Project Guidelines (BSc Computer Science Single Honours Students only)?

To ensure that my project is in line with the BCS Project Guidelines, I will first define the scope of my project clearly and concisely. I will then develop a project plan that outlines the tasks and the resources that will be needed, and the timeline for completion (the Gantt Chart). I will also identify the risks (risk table below) that could impact my project and develop mitigation plans. Throughout the project, I will keep monitoring my progress and ensure to update the project plan of the progress of my project and any changes that have happened to the project.

In addition to the general guidelines, I will also make sure to follow the specific BCS Project Guidelines which includes ensuring that my project is a significant piece of work that is relevant to computer science, that it is completed independently, that it is submitted in the form of a written report, and that it is assessed by a project supervisor and an external examiner

Time and Resource Planning

Will Standard Departmental Hardware be used? YES (standard computer with webcam to be used)

Will Software which is already available in department be used? YES (will be developed as an example in XCode)

Will the project require any Programming? YES (Python)

If YES please list the (potential) Programming Languages to be used (including any IDEs and Libraries you may make use of):

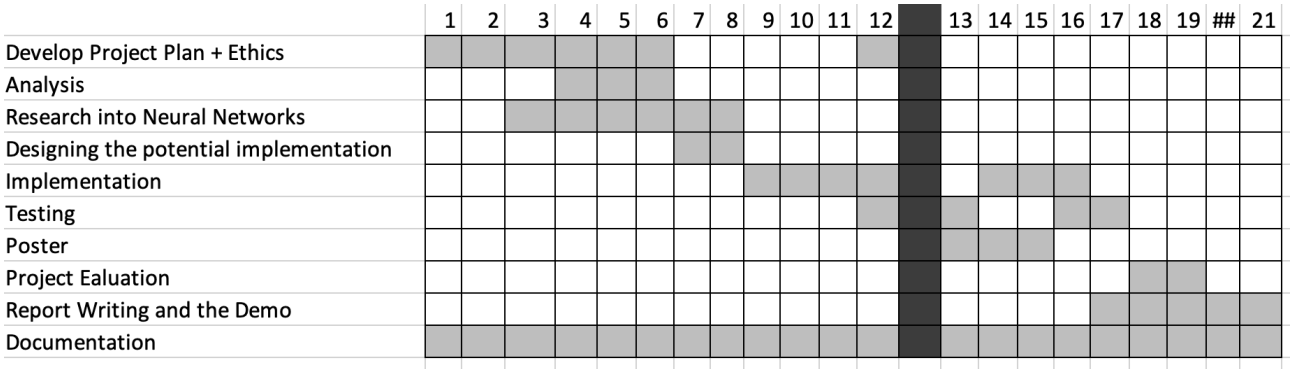
Programming Language – Python
IDE – XCode, Visual Studio is planned as the backup IDE incase any issues with XCode arise.
Libraries potentially to be used:
TensorFlow
DLib (python adapted implementation)
YOLO (A facial recognition library)
PyTorch

Table of Risks (*if non Standard Hardware and/or Software to be used please also include backup options/ contingency plans here)*:

Risk-id Description	Probability/Likelihood of occurring	Best practice prevention measures	Remedy
Loss of work	**low**	**To keep backups stored elsewhere and also make backups on the same computer as the program progresses in production.**	**To load an old backup and re-do the lost work.**
Hardware Failure	**Low**	**To keep backups in the cloud so that I can access them from another computer if needed.**	**To use computers within the lab and from an old backup before my personal computer broke**

Falling behind the plan	**Low**	**Create achievable goals within the Gannt Chart**	**To look back at the Gantt Cart and make changes to ensure the goals are achievable**
Inaccurate data (queue times) being produced by the implementation	**Medium**	**Train the neural network on a much wider data set to improve the generalizability**	**Keep monitoring the performance of the model and give it more data if needed.**
False Recognition (the program may recognise things as people when they are not)	**Medium**	**Train the neural network with a wide data model**	**To go back and train the model more, ensuring to monitor progress**
Privacy Concerns	**Medium**	**Only use stock images of queues held up to the system to ensure I do not cross any GDPR regulations.**	**Review the GDPR Checklist**
Technical Issues	**Medium**	**Thoroughly test the software before the demo and keep track of past bugs and changes**	**Go back to a previous version of the software if a new change is causing issues.**

Gantt Chart (must include milestones and deliverables):



References

Please include a list of References used in this Plan (using Harvard reference style):

Waiting-Time Estimation in Bank Customer Queues using RPROP Neural Networks by R. K. Jena, S. K. Rath, and R.Panda: https://www.sciencedirect.com/science/article/pii/S1877050918314339

YOLO: Real-Time Object Detection with Region Proposal Networks by Joseph Redmon, Santosh Divvala, Ross Girshick, and Ali Farhadi: https://arxiv.org/abs/1506.02640

A time series forecasting approach for queue wait-time prediction by A. S. Kumar and H. V. P. V. N. Rao:https://www.diva-portal.org/smash/get/diva2:1458832/FULLTEXT01.pdf

Queue Time Estimation in Checkout Counters Using Computer Vision and Deep Neural Network by Muhammad Atif Irfan, Muhammad Zohaib, and Muhammad Aamir Shahzad: https://iopscience.iop.org/article/10.1088/1742-6596/1964/6/062108/pdf

TensorFlow 2: A Practical Guide for Beginners by Anirudh Koul:https://www.tensorflow.org/tutorials/quickstart/beginner

Learning PyTorch: A Hands-On Guide for Beginners by TutorialsPoint: https://m.youtube.com/watch?v=c36lUUr864M

Computer Science CSC-30014 Project GDPR and Ethics Checklist 2023-24

STUDENT NAME: Thomas Herward

STUDENT NUMBER & E-MAIL: 20014189 - x3d82@students.keele.ac.uk

PROJECT TITLE: Own Idea - Queue management system with photo recognition to estimate wait time

SUPERVISOR NAME: Dr Vishwash Batra

GDPR Check

Does your project involve the use or collection of "personal data" for which permission will not have been explicitly granted? (Before answering, please read and carefully consider the GDPR Check Guidance at the end of this form).	No

Ethics Check

Will your project involve the use of human participants or capturing human data? (Before answering, please read and carefully consider the Significant Ethical Concern Checklist, below). Please Note: software evaluation by any other person counts as human participation. If you ask people their opinions about software or use their data in any way, you need to seek ethical approval first. If you answered "Yes" to this question you must discuss your plans with your supervisor and, by end of week 12 of Semester 1, complete the Computer Science Final-Year Project Ethical Review Application Form and prepare a Participant Information Sheet and Consent Form using the templates that can be found at the end of that application form.	No

Significant Ethical Concern Checklist

Could the project expose the participants or the project student to images and/or information that they might find distressing (e.g. pictures or descriptions of injuries, symptomatic health conditions, or atrocities, or pictures or descriptions of tumours or cancerous cells, or creatures in distress)?	No
Does the project involve deception of the participants?	No
Could the project uncover information about identifiable individuals that could cause embarrassment or distress to one or more of those individuals (e.g. evidence of illegal or unethical behaviour, such as fraud or illegal drug use or a personal revelation)?	No
Could the project cause pain, discomfort or risk to the participants and/or the project student?	No
Will the project involve participants who are vulnerable in any way? (e.g. participants who are under 18, or who are mentally or physically impaired, or participants who may feel under pressure to participate.)	No
Does the project involve recall or discussion of personal or sensitive memories?	No

Does the project involve a significant risk of participants later regretting taking part?	No
Does the project involve procedures which are likely to provoke interpersonal or inter-group conflict?	No

If the answer to any of the Significant Ethical Concern Checklist questions is "Yes" (or you think "Maybe") you must discuss your project and aims with your supervisor and with the CSC-30014 Module Co-ordinator to assess whether an appropriate level of ethical scrutiny might be required via the completion of the *Faculty of Natural Sciences (non-Psychology) Research Ethics Application Form*.

GDPR Check Guidance:

Personal data includes any and all of: names, addresses, emails, phone numbers, bank details, employment details, IP addresses, date of birth, medical or health data, images, video or audio recordings.

If you answered "Yes" you must not proceed with your project.

It is illegal under European GDPR legislation to make use of personal data without explicit permission. Discuss your project with your supervisor and revise your plans to ensure you do not risk illegal use of personal data.

Note. Even if personal data is publicly available on the Internet, it must not be used without permission. (Also note that you cannot contact individuals to request permission to use their on-line data without prior ethical approval to do so).

It is strongly recommended that you either:

1. use non-personal data for your project, or
2. use existing, well-established, publicly available databases or data repositories, for example: https://archive.ics.uci.edu/ml/index.php, https://physionet.org/ or https://www.kaggle.com/ etc. (A list of acceptable data repositories is maintained on the CSC-30014 KLE pages.) You might also see, for example, https://blog.scrapinghub.com/web-scraping-gdpr-compliance-guide) for further information.

I confirm that the responses are correct and that the project, as proposed, is GDPR compliant and that ethical approval will be sought if required and that any work requiring ethical approval will not take place unless ethical approval has been granted. If, during the course of the project work, any of the information supplied on this checklist changes substantially a new checklist will need to be completed and then brought to the attention of the School's Ethics Advisory team.

Signed (Student) T.Herward	Date: 29/10/2023

I confirm that I have read the form and that the project, as proposed, is GDPR compliant and that, to the best of my knowledge, the ethical information is correct.

Signed (Supervisor) Vishwash Batra	Date: 8th Nov 23

Electronically typed signatures and dates *are* acceptable.