Machine Learning for Queue Detection

White Paper

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A whitepaper by

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Abstract/Problem

Retail stores are annually losing billions in sales due to mismanaged queues. Customers prefer convenience and want to spend a minimum amount of time in queues.

This paper discusses how long queues result in customer dissatisfaction, which in turn affects sales, along with how Computer Vision can be used to solve this issue. The solution however, comes with numerous challenges. Complex calculations are needed to take into account the majority of unpredictable behavioural pattern of customers.

We also discuss how Zone24x7 has used Computer Vision along with proprietary algorithms to solve the business problem. It is a market-ready and proven solution, which overcomes all the challenges mentioned in this paper.

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1. Introduction

Brick and mortar stores have endured the exponential growth of online retail and account for 81% of total sales in the $5 trillion retail industry [US Census Bureau, "Retail Trade Report", 2018]. This shows that brick and mortar stores will not be going anywhere anytime soon. A key factor as to why physical stores produce a significant portion of retail sales: tangible experience. It allows consumers to try or inspect the product of interest before making a purchase e.g. being able to try a piece of clothing or choosing the freshest fruits and vegetables.

In a world where convenience largely determines customer satisfaction, brick and mortar stores are not an exception to this rule. Convenience is a major factor when it comes to choosing between competing stores [Statista, "How do you normally find and choose a retailer to shop at?", 2019]. There are many pain-points that retailers can fix/improve when it comes to convenience.

1.1. Problem - Long Queues

One key challenge retailers face daily is making sure that long queues do not form at the cashier, especially during peak hours. About 86% of US consumers have left a store due to long queues and retailers are losing an estimated $38 billion in potential sales [Retail Customer Experience, "Retailers Losing Billions in Revenue Due to Long Lines", 2018].
As a remedy, retailers are forced to increase the number of employees or Point of Commerce (PoC) counters to handle the customer flow smoothly. Effectively planning the resources to maximize the profit has always been a challenge for the industry. Some companies practice ad-hoc methods of resource allocation as and when there is a queue formed at the PoC counters. Handling queues requires constant observation of the queuing area and many calculations. Relying completely on employees to make these decisions leads to inaccuracy. As a result, the queues will not be managed well and it will lead to customer dissatisfaction and eventually a loss in potential sales.

This paper discusses the latest technology that can be used to mitigate long queues which in turn prevent customer dissatisfaction and a loss in potential sales.

Summary of the introduction

Customer satisfaction is key in the retail industry. When huge queues are there in the paying PoC counters, the buying decisions of the customers are negatively influenced.

2. Solution

2.1. Dawn of Deep Learning

Machine learning (ML) is the ability of the computer to process data and create algorithms to predict results according to the data provided.
Deep learning is an advancement of ML and can better process data to provide more complex predictions.

2.2. Computer Vision

A particular use case of Deep Learning is Computer Vision. It tries to mimic how humans see and process visual information by using a structure known as Convolutional Neural Networks (CNN). Once the video is fed into the CNN, it will extract necessary features automatically from each frame in the video and provide a prediction.

2.3. How can Computer Vision help manage queues?

Existing security cameras can be used in the store near queuing areas. Using a Computer Vision model, the cameras will be able to understand the number of customers in the queue. Once the queue reaches a particular threshold of customers, it would be able to identify this as a long queue for the employees to take action.

Students and researchers are racing to create the most accurate and fastest processing Computer Vision models e.g. Darknet, YOLO and VGG19. These models are deployable by anyone for problems such as monitoring queues.

This sounds great right? Well, it is not as easy to implement as it sounds. The available models are not developed for specific problems. They are general models for detecting objects. There are many challenges one will face when trying to implement a Computer Vision model at a queuing area. These challenges will be discussed in detail in section 3.

Summary of the solution

Cameras set at queueing areas can be used along with a Computer Vision model to identify long queues. There are however many factors to take into account that makes creating such a model difficult.

3. Challenges

As mentioned earlier, customers despise queues and the store could lose out on potential sales. Hence, to prevent customer dissatisfaction, one should monitor:

a. The number of customers at the queueing area, which would provide the length of the queue.
b. How long an average customer has to stay in the queue.

The average time a customer spends in a queue should be monitored because the queue could be short but not fast moving. The average waiting time in the queue can be calculated and displayed to the customers.

However, Monitoring these two factors leads to multiple complex challenges. We will discuss three challenges faced when developing a Computer Vision model for queues.

Figure 1: Complex queues at a retail store

3.1. Challenge 01: Occlusion of customers in a queue

Occlusion is when one object(could also be another customer) blocks the view of another object, which the camera is trying to identify. It results in the Computer Vision model not being able to detect if there is a customer in the queue thus, producing inaccurate results. This commonly occurs where there are other people such as children accompanying the customer at the queue.

Figure 2: Occlusion at a retail queue

3.2. Challenge 02: Accompanying guests

Brick and mortar stores attract a wide demographic. Customers (most the time) tend to travel with a companion e.g. partner, children or friends. When joining a queue at the store, so would these accompanying guests of the customer. Accounting for these guests would produce false positives for the queue length because the customer and accompanying guests usually exit the queue simultaneously.
Predicting if the person at the queue is a customer or accompanying partner is extremely challenging when using only visual data.

Figure 3: Accompanying guests at a retail queue

3.3. Challenge 03: Movement of customers within the queue

Sometimes, Human behaviour can be unpredictable even for us to judge. Now, imagine a computer trying to identify if a customer is in the queueing area or just shopping for items near the queue. A customer could also just be passing by the queueing area or leaving the queue to purchase more items that came to mind at the last moment.
Due to such scenarios, various variables need to be taken into account to ensure that the customer has to be included in the queue.

Figure 4: Complex customer movements in a queuing area

The challenges mentioned above are just three of the many challenges when trying to monitor and manage a queue.

Summary of the challenges

Implementing Computer Vision models comes with its challenges. The challenges are based on identifying if the customer is actually part of the queue and how long he/she is actually part of the queue.

4. Market-Ready and Proven Solution

The team specializing in Computer Vision at Zone24x7 has developed a product to monitor and manage queues.

4.1. How does the proposed solution add value to retail stores?

Queue Manager helps manage queues in the following three ways:

1) In real-time, it can detect the formation of long queues and inform employees to take action such as opening more PoC counters.
2) Taking into account all the sporadic behaviour of customers in a queue, it can accurately calculate the average queueing time. This can be used to distribute customers efficiently between the available PoC isles by displaying the current fastest isle.
3) After accumulating enough data of the queues, the model can also predict queueing times for different days and for particular times of the day. The store employees can then allocate the appropriate number of employees for each specific day and time. Efficient resource allocation will lead to cost-saving.

4.2. Latest metrics of Queue Manager

We measured the following Key Performance Indicators against baseline statistics of the store to measure the positive effect the introduction of the Queue Management system had within the designated scope.

- Average Wait Time of customers in a line dropped
    - Wait Time over 8 mins (long Queue) disappeared totally 100%
    - Shorter Ques of 3 to 50 mins have dropped by 60%

- The Rate of Abandonment calculated through observations and surveys were positively affected
    - Balking (Customers who see the long line and decide to not join at all) dropped 50%
    - Reneging (Customers who wait in line and abandoned mid way) dropped by 70%

- Visible shorter Queues or No Queue made shoppers who enter the store buy more resulting in
    - transaction growth of the store on average of 5.2%
    - Increased basket size of purchases by an average of 3%

- As a result a higher average revenue increase was observed of 1.5%

- Customer surveys done during the period showed an increase in customer satisfaction indexes and showed increases in customer propensity to recommend the store to peers.

4.1. Technology behind the proposed solution

The foundation of the solution is built using a Computer Vision model. However, as mentioned earlier, there are a lot of challenges that need to be overcome in order to make sure that this model can accurately analyse queues and provide an accurate queueing time to customers.

We plotted almost every scenario that could occur in a queue to create advanced algorithms to track the sporadic behaviour of customers in a queue.
One major challenge that we overcame is the movement of customers within the queue. The customer could be just passing by, shopping for items near the queue or exiting the queue at random points in time and returning. Here are just some of the mechanisms used to accurately detect behavioural patterns in queues:

- The velocity of each customer in the queueing area is tracked. If the velocity exceeds a certain threshold, the customer is identified as just moving through the queueing area.
- Each customer entering the queueing area is tagged, if they leave spontaneously and join the queue after a set amount of time, they are still included in the queue.
- The model also tracks customers, who join the middle of a queue, which affects average queueing time.

These results are produced using a single camera in the queueing area. Queue Manager needs only real-time video input of the resolution 1280x380 or 640x360. Therefore, It can be implemented in stores with the existing infrastructure as most stores have cameras near queueing areas.

Summary of the market-ready and proven solution
A team specializing in Computer Vision at Zone24x7 developed Queue Manager. It has proven to be accurate and increase the number of customers purchasing items compared to the total number entering the store.

5. Conclusion

This paper discussed how long queues result in customer dissatisfaction, which in turn affects sales, along with how Computer Vision can be used to solve this issue. The solution however, comes with numerous challenges. Complex calculations are needed to take into account the majority of unpredictable behavioural patterns of customers. Also discussed are how Zone24x7 used Computer Vision along with proprietary algorithms to solve the business problem. The available general models are not developed for specific problems and hence improved Computer vision algorithms along with comprehensive problem specific machine learning models are necessary. These have paved the way for a market-ready and proven solution, which overcomes all the challenges.

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