Self-Checkout Smart Store System

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***Abstract*—Indian retail industry has emerged as one of the most dynamic and fast-paced industries It accounts for over 10% of the country's gross domestic product (GDP) and around 8% of the employment, grocery shopping habits are changing due to technological advancements. However, the online grocery market is still in its early stages, with only 0.15% of Indians buying groceries online. The offline retail market has some limitations including long queues and cashier errors, the model offers customers a seamless, efficient shopping experience while enabling retailers to reduce labour costs. To overcome this, we came up with the self-checkout smart store system this represents a transformative approach to retail, leveraging advanced tech- neologies like computer vision, machine learning, and a Digital Payment System to streamline the checkout process. This system will be utilizing a machine learning model and TensorFlow an open-source machine learning library, MobileNetV2 a pre-trained deep neural network architecture for object identification. For this purpose, we created a dataset that consists of product images consisting of 4500 images that will be used for model train- ing. Motivated by the desire to revolutionize retail, the project fills a research gap by integrating comprehensive technological solutions. The prototype implementation in a real-world retail setting demonstrates the feasibility and potential of this forward- thinking self-checkout smart store system, positioning it as a catalyst for the future of retail shopping.**

***Index Terms*—Machine learning, Computer vision, Digital payment system, MobileNetV2, TensorFlow, Neural network.**

INTRODUCTION

In today's fast-paced world, customers waiting in line is abig problem for businesses. A whopping 75% of customersleave if they wait too long, and 74% would rather go to a competitor for faster service. This waiting game costs businesses £12 billion each year! To break it down, £6.4billion goes to other stores because frustrated customers decide to shop somewhere else. The remaining £5.6 billion is lostbecause people leave the store before they even buy anything. Long queues at billing counters are due to limited billing counter availability during peak times, inefficient staffing with inexperienced personnel, and complex payment procedures.

Thus, the question is raised: what would happen if we could use cutting-edge technology to tackle this problem and assist businesses make more money? Already some solutions are available which have challenges like limited

scalability in

assistance can impact the overallefficiency of these systems.

To overcome these lacunae we developed a solution, the Self-Checkout Smart Store System. This approach aims to rev-olutionize the traditional shopping experience by eliminating the frustrations associated with waiting in line.

The self-checkout store system revolutionizes the shopping experience through advanced technology, automation, and a seamless checkout process. Utilizing computer vision, sensor technology, machine learning, and a Digital Payment System, customers can check in via a smartphone app, detect items within the shopping cart via camera attached in cart, and automatically calculate real-time costs.

To validate the efficacy of our self-checkout system, we conducted rigorous testing using a carefully curated dataset. This dataset comprises 18 different products, each representedby 250 images, totaling 4500 pictures. These diverse product images ensure that our system is well-trained to handle a va- riety of items, providing a robust and comprehensive solution for real-world retail scenarios.

The machine learning model achieved an accuracy of 94.6 percent, indicating that it correctly predicted outcomes for 94.6percent of the cases evaluated. This high accuracy suggests the model's effectiveness in making accurate predictions based onthe given dataset.

The existing systems using various sensors like- pressure sensor, weight measurement sensor, RFIDs, Distance & Dimension measurement that will track what/when items are being picked up or kept back on the shelf and various cameras. Instead of this we are attaching a QR code and esp32 cam to the shopping cart- by scanning the QR code the shopping cart will be linked to the customer's virtual card and esp32 cam will help in detecting the products which are placed in the cart and it will automatically be added to his/her virtual cart by our underlined ML Model. And at the time of exit customer just have to scan the QR which will be generated once he/she pay the bill amount.

I. LITERATURE REVIEW

The implementation and optimization of self-checkout sys- tems have become pivotal in the modern retail landscape, offering convenience and efficiency to both retailers and consumers. This discussion focuses on three significant pa- pers exploring various aspects of self-cashier-less shopping experience. It addresses challenges related to customer ed- ucation and trust, loss prevention, larger retail environments, high initial costs that act as a barrierfor smaller businesses, and complex user interfaces that may confuse customers. Accuracy in product recognition and the lack of personalized customer

checkout technologies, namely "Self-Checkout System

Using RFID (Radio Frequency Identification) Technology: A Survey," "Shop and Go: An Innovative Approach Towards Shopping Using Deep Learn- ing and Computer Vision," and "Just Walk-Out Technology and Its Challenges: A Case of Amazon Go. "The Self-Checkout System Using RFID Technology" paper delves into the challenges and parameters associated with implementing RFID technology in self-checkout systems.[7][10] It addressesissues such as tag accuracy, interference, and the overall cost of implementation. The work primarily revolves around over- seeing the integration and optimization of RFID self-checkout systems. This involves ensuring the accuracy of RFID readers and antennas, managing the cost of implementation, and im- plementing robust security measures to safeguard user privacythrough RFID tags. Collaborative efforts with cross-functionalteams play a crucial role in achieving seamless integration, accuracy, and user-friendly experiences. The "Shop and Go" paper explores an innovative approach to self-checkout by incorporating Deep Learning and Computer Vision.[5] Key is-sues highlighted include user privacy concerns, adoption rates, and overall user experience. The work encompasses overseeingthe deployment of the "Shop and go" autonomous shopping system. This includes integrating advanced security proto- cols and surveillance systems, addressing user privacy con- cerns, and optimizing the system's performance through high-performance computing and efficient algorithms. The goal is toensure the system's accuracy, security, and user privacy while maintaining compatibility with existing retail infrastructure.[9]The "Just Walk-Out Technology and Its Challenges" paper focuses on Amazon Go's revolutionary

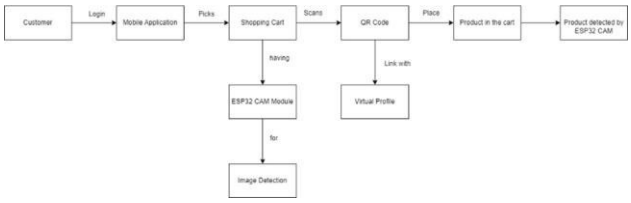
and the user experience learning curve. The work involves overseeing the deployment of Amazon Go's "Just Walk-

Out" technology, ensuring sensor accuracy through advanced technologies like cameras and weight sensors. Additionally, robust data privacy and security measures are implemented, including secure data storage systems, encryption techniques, and access controls. The aim is to protect customer information from unauthorized access and data breaches while providing a seamless and efficient cashier- less shopping Self-Checkout Smart Store System Page—6 ex-perience. In conclusion, these papers collectively underscore the multifaceted nature of self-checkout systems, emphasizing the importance of accuracy, security, user privacy, and seamless integration with existing retail infrastructure. The collaborative efforts and strategic deployment of advanced technologies are pivotal in realizing the full potential of self- checkout systems and reshaping the future of retail.[3][5]

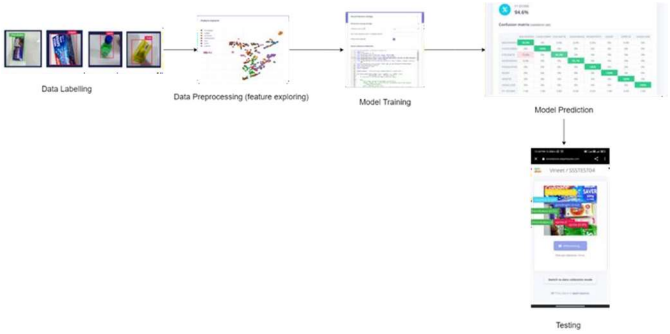
Some sensors we are using for this

1) ESP32 CAM: The ESP32 camera in a Self-Checkout Smart System can be employed for object recognition, enabling accurate tracking of items in the cart, user authentication through facial recognition, and real-time monitoring for security and assistance, enhancing overallefficiency and user experience.

Fig. 4. ESP32 CAM (Camera Module for Object Detection)



2) Arduino UNO: The Arduino Uno plays a pivotal rolein several key functions. Firstly, it facilitates seamless sensor integration to detect and track items



in the shop- ping cart, ensuring accurate and efficient self-checkout processes. The Arduino Uno also serves as the brain behind the user interface, allowing customers to interact with the system through buttons or a touchscreen, en- abling smooth item scanning and payment procedures. Additionally, the Arduino Uno contributes to transaction processing, interfacing with a Digital Payment System to ensure secure and reliable financial transactions during the self-checkout experience. Furthermore, the versatil- ity of Arduino Uno extends to RFID integration, provid- ing enhanced item identification and tracking capabili- ties, ultimately streamlining the entire checkout process for improved efficiency and customer satisfaction.

Fig. 5. Arduino UNO

II. ARCHITECTURE AND METHODOLOGY

The self-checkout smart store system comprises three inter-connected modules.

A. Architecture

1) ***Customer Interaction Module****:* The system architecture begins with customers scanning a QR code on the cart, linkingit to their account. This initial step establishes a unique identifier for the cart, ensuring a personalized shopping experience. Subsequently, as customers add items to their physical cart, the system mirrors this in real-time by updating their virtual cart, creating a seamless connection between the physical andvirtual shopping experiences.

Fig. 1. Architecture of Customer Interaction Module

2) ***ML Model Module*** *:* The ML Module trained on a dataset of 4500 images featuring 18 different products, it excels in recognizing items. Using this learned knowledge, the module efficiently identifies products as they are placed in the shopping cart, enhancing the system's ability to track purchases accurately.

Fig. 2. Architecture of ML model module

3) ***Real-Time Transaction Handling*** *:* The culmination of the shopping journey involves the

automatic generation of a bill, reflecting the items in both the physical and virtual charts. The generated bill is then presented to the customer, who can conveniently pay through a mobile application. This payment method leverages the integration of a secure and user-friendly mobile payment system, ensuring a smooth and efficient transaction experience.

B. Methodology

*1) **Customer Interaction Module**:*

- User Authentication: Customers initiate the self-checkout process by logging into their profiles using the dedicated

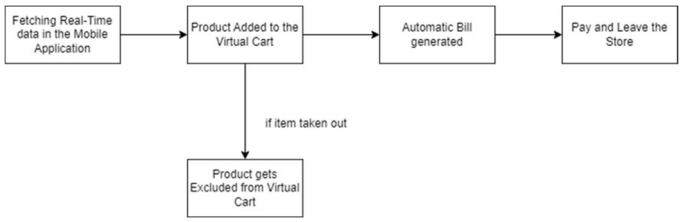


Fig. 3. Architecture of Real-time Transaction Handling

mobile application. This step ensures a personalized and secure shopping experience.

- QR Code Scanning: The physical shopping cart is equipped with an ESP32 CAM. Customers scan a QR code on the cart to establish a connection between their virtual cart and the physical cart, enhancing the accuracy of the shopping transaction.
- Real-Time Product Detection: The ESP32 CAM contin- uously detects and updates the virtual cart in real-time as customers add or remove items, providing an accurate representation of the shopping experience.

*2) **ML Model Module**:*

- Dataset Creation: We created a dataset by capturing 250 images for each of the 18 distinct products, resulting ina comprehensive dataset of 4500 images.
- Data Preprocessing: The collected images undergo pre- processing to extract relevant features, enhancing the model's ability to identify and recognize products effec- tively.
- Image Resizing: The collected images are resized to ensure a consistent input size for the machine learning model, facilitating uniform feature extraction.
- Grey Scaling: Converting images to grayscale simplifies the data, reducing computational complexity and aiding the model in focusing on essential features rather than colour variations.
- Normalization: Normalizing pixel values to a standard scale enhances model convergence during training, pre- venting certain features from dominating the learning process.
- Augmentation Techniques: To diversify the dataset, aug- mentation techniques such as rotation, flipping, or zoom- ing may be applied. This helps the model generalize better to variations in product placement.
- Feature Generation: After data preprocessing, relevant features are generated from the curated dataset. These features serve as distinctive characteristics that the ma- chine learning model can use to identify and differentiate between the various products.
- Model Training: The pre-processed data is used to train the machine learning model, teaching it to accuratelyidentify products placed in the shopping cart.
- Model Testing: Rigorous testing is conducted to validate the model's accuracy and reliability, ensuring its effec- tiveness in real-world scenarios.
- Real-Time Prediction: Once trained and tested, the modelis integrated into the overall self-checkout system. Inreal-time, as customers place items in the shopping cart equipped with the ESP32 CAM, the model applies its learned patterns to predict the identity of each product.

*3) **Real-Time Transaction Handling** :*

- Continuous Data Updates: The mobile application is con- tinuously updated with real-time data, reflecting changes in the virtual cart as customers add or remove items.

Automatic Billing: The system automates the generation

- of bills, considering the contents of both the physical and virtual carts, streamlining the checkout process.
- Integrated Payment Process: A user-friendly payment process is integrated into the mobile application, allowing customers to conveniently and securely complete trans- actions before leaving the store.

4) Flowchart :

Algorithm: Self-Checkout Smart Store System

Input:
• Customer needs to feed their details in our Mobile Application. • Place all products in shopping cart which is attached to the ESP32 CAM.
Output:
• After a consumer completes their profile on the mobile application, a QR code is created. • An online Bill is generated. • After a customer pays their bill, a QR code is created, which they may scan to exit the store.
Procedure:
• User Login to our Mobile Application. • scans the shopping carts QR code attached to the shopping cart, which connects to the user's virtual cart. • When a consumer places a product to their cart, the ESP32 CAM will immediately identify it and add it to their virtual cart. • Lastly Bill is generated, which may be paid with our Mobile Application. • A QR code is generated which is used to Exit the store.
End Algorithm

IV. Results

Fig 6. Feature Explorer

Our Model achieved 94.6% F1 Score for the given set of data provided. The F1 score is a metric commonly used in binary classification problems, but it can also be extended to multi-class classification. It combines precision and recall into a single metric and is particularly useful when the class distribution is imbalanced.

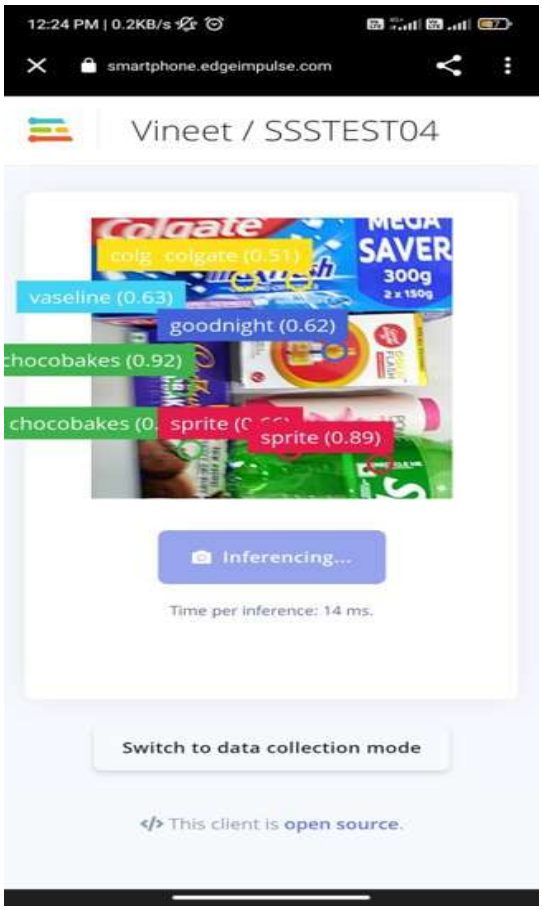


Fig 7. Testing

This is the Testing for object detection via our Mobile phone camera. Here we placed all the products in-front of our mobile phone and the ML Model able to detect all the products.

Fig 8. Mobile Application

This is the Mobile Application where customers can see all the products which are added to their Virtual cart by ESP32 CAM Module and can pay through mobile application and leave the store.

V. Conclusion

Self-checkout smart stores revolutionize the shopping ex- perience by providing enhanced convenience through quick payments and eliminating long queues, saving customers valuable time, and reducing frustration. The user-friendly interface contributes to improved customer satisfaction by minimizing checkout bottlenecks and reducing human errors. Additionally, the integration of advanced security measures, including surveillance cameras, leads to a reduction in theft and fraud, enhancing store profitability. In response to the growing demand for contactless experiences, these smart stores offer a safer shopping option by minimizing physical interactions during the checkout process. Overall, the adoption of self-checkout technology brings about a more seamless, efficient, and secure retail environment, meeting the evolving preferences of modern consumers.

- Enhanced Convenience: Self-checkout smart stores pro- vide shoppers with a more seamless and efficient shop- ping experience. Customers can quickly make payments, and exit the store without waiting in long queues, saving valuable time, and reducing frustration.
- Improved Customer Satisfaction: With fewer checkout bottlenecks and a user-friendly interface, customers expe- rience higher satisfaction levels when shopping at smart stores. The reduction in human error during the checkout process also contributes to a more positive shopping experience.
- Reduced Theft and Fraud: The integration of advanced security measures, such as surveillance cameras, helps minimize theft and fraud instances, improving store prof- itability and loss prevention efforts.
- Contactless Shopping: In growing demand for contact- less experiences, self-checkout smart stores offer a safer shopping option, minimizing physical interactions.

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