AI-Driven Smart Cart System For Automated Billing And Real-Time Product Recognition

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Abstract- *AI technology has completely changed a number of industries, and the retail industry is no different. This paper offers a thorough analysis of the use of artificial intelligence (AI) in smart cart implementation, with the goal of revolutionizing the conventional shopping experience. Our intelligent shopping cart system utilizes cutting-edge artificial intelligence algorithms, specifically the YOLOv8 model for barcode recognition and the Python library for decoding, to provide smooth product scanning and checkout procedures. To improve accuracy and security, we suggest a phased switch from barcode to QR code technology. We see a future where long lines and laborious checkout processes are replaced with quick and easy shopping experiences by distributing smart carts with AI capabilities. This study opens the door for novel developments in customer engagement and corporate operations while also adding to the continuing conversation about the application of AI in retail settings.*

I. INTRODUCTION

Retail shopping has undergone a profound transformation with the advent of artificial intelligence, offering smarter, faster, and more efficient customer experiences. Traditional brick-and-mortar stores have long relied on manual checkout systems, which are prone to inefficiencies such as long queues, human errors, and slow processing times. To overcome these limitations, the AI-powered smartshopping cart introduces a fully automated shopping experience by integrating real- time object detection, product recommendations, voice assistance, and automated billing. The system leverages YOLOv8, a state-of-the-art object detection model, to instantly recognize products in the cart, thereby eliminatingthe need for barcode scanning. The recommendation system, driven by collaborative filtering, enhances the shopping experience by suggesting frequently bought-together products, promoting cross-selling, and improving customer satisfaction. Additionally, voice assistance provides real-time feedback, confirming product additions and notifying customers of discounts, making the interaction more intuitive and engaging. The automated billing feature instantly calculates the total cost, applies dynamic discounts, and generates an accurate bill, ensuring a seamless checkout process with minimal human intervention. This AI-powered system offers numerous benefits, including improved accuracy, reduced checkout time, and enhanced customer engagement. Moreover, it boosts retailer profitability through personalized recommendations and cross-selling opportunities. Real-world implementations by retail giants like Amazon Go and Walmart demonstrate the effectiveness of AI in transforming the retail landscape, providing faster, contactless, and more efficient shopping experiences. The smart shopping cartaims to replicate these innovations by making AI-driven automation accessible to mid-sized and smaller retailers. Despite its advantages, the system also presents challenges such as ensuring accuracy in crowded retail environments, maintaining data privacy, and scaling the infrastructure. Nevertheless, the future scope of the smart shopping cart includes integrating facial recognition for personalized offers, mobile app integration for seamless payments,and cloud-based analytics for customer behavior insights. By combining cutting- edge AI technology with practical retail applications, the smart shopping cart represents a revolutionary step toward smart retailing, offering both efficiency and convenience for customers and retailers alike.

II. RELATED WORK

The concept of smart shopping carts has gained significant traction in the retail industry as companies strive to enhance efficiency and improve customer experiences. Traditional checkout systems, which rely on manual barcode scanning, often result in long queues, human errors, and delayed service. To address these issues, major retailers have adopted automated checkout solutions by leveraging artificial intelligence, computer vision, and machine learning technologies.

Amazon and Walmart are among the pioneers in implementing smart checkout systems. Amazon introduced its cashier- lessstores,brandedasAmazonGo,which allow customers to pick items and leave the store without manual checkout. The system uses a combination of computer vision, deep learning algorithms, and sensor fusion to detect the products taken bycustomers.Theitemsareautomatically billed

to the customer's Amazon account, making th shopping experience fast. While existing solutions have shown promising results, they still face challenges related to scalability, accuracy, and privacy concerns. Maintaining consistent detection accuracy in crowded retail environments and managing large volumes of real-time data remain key hurdles. Furthermore, smaller retailers often find it difficult to adopt such systems due to high infrastructure costs.

III. PROPOSED SOLUTION

The proposed solution aims to transform the traditional retail shopping experience by developing an AI-powered smart shopping cart equipped with real-time object detection, automated billing, voice assistance, andpersonalized recommendations. This innovative system addresses the inefficiencies of manual checkout processes by enhancing speed, accuracy, and customer convenience through artificial intelligence and machine learning.

The core of the proposed solution is YOLOv8 (You Only Look once, version 8), a cutting-edge object detection model known for its speed and accuracy. YOLOv8 processes entire images in a single pass, making it highly efficient for real-time detection of multiple products in the cart. When a customer places an item into the cart, the camera module captures the image and YOLOv8 identifies the product by detecting its shape, size, and visual features. The system automatically adds the product's name, quantity, and price to the bill without the need for manual barcode scanning. This real-time detection significantly reduces checkout time and eliminates human errors, making the process faster and more reliable. To enhance the shopping experience, the solution incorporates a recommendation engine based on collaborative filtering. This recommendation system analyzes customer behavior, such as previously purchased items or frequently bought- together products, to suggest complementary items. For example, if a customer adds pasta to their cart, the system may recommend past a sauce,garlic bread, or cheese. This cross-selling strategy increases average cart value and improves customer satisfaction by offering relevant product suggestions.

Another key feature of the proposed solution is voice assistance, which provides real-time auditory feedback. The cart uses Google Text-to-Speech (gTTS)or Amazon Polly to announce the addition of products, confirm quantities, and notify customers of any applied discounts or promotional offers. This hands-free interaction makes the shopping experience more intuitive and user-friendly, especially for visually impaired customers.

The automated billing system calculates the total cost of all detected products, applies dynamic discounts, and generates the final bill. The system supports multiple payment methods, including contactless payments and digital wallets, ensuring a seamless and efficient checkout process. This automation not only reduces labor costs but also improves accuracy by eliminating manual billing errors.

The proposed solution also includes data analytics capabilities. The system captures customer purchase data, enabling retailers to analyze shopping patterns, identify popular products, and optimize inventory management. Real-time analytics also allow retailers to offer personalized discounts and promotions, driving customer engagement and loyalty.

To ensure scalability and flexibility, the solution is designed to be compatible with both local servers and cloud infrastructure, making it suitable for small and large retailers alike.

Additionally, security measures such as data encryption and anonymization are implemented to protect customer privacy.Overall, the AI-powered smart shopping cart offers a comprehensive and scalable solution to modernize retail shopping. By integrating real-time object detection, personalized recommendations, voice assistance, and automated billing, this system streamlines the checkout process, enhances customer satisfaction, and boosts retailer profitability.

IV. METHODOLOGY

Dataset Preparation

The first step in building the AI-powered smart shopping cart involves preparing the dataset. For this project, we use the COCO (Common Objects in Context) dataset, which is widely recognized for object detection tasks. The COCO dataset contains over 330,000 images, including more than 200,000 labeled images with around 1.5 million object instances. These instances span 80 different object categories, including retail products such as packaged goods, beverages, fruits, and vegetables, making it suitable for training the object detection model.

The dataset undergoes preprocessing before training. Each image is resized to a consistent dimension of 640x640 pixels to ensure uniformity. Data augmentation techniques such as random cropping, flipping, rotation, and brightness adjustments are applied to increase the model's generalization ability. This step ensures the model can accurately detect

products in real-world retail environments, even when lighting conditions or angles vary. The dataset is then split into training (70%), validation (20%), and testing(10%) sets to evaluate the model's performance.

Exploratory Data Analysis(EDA)

Before proceeding with model training, we conduct exploratory data analysis (EDA)to understand the dataset's structure and distribution. This includes visualizing the distribution of product categories, identifying frequently occurring items, and detecting any potential class imbalance. Scatter plots, histograms, and bar charts are used to analyze the relationships between different features and detect patterns. The analysis helps in identifying potential anomalies or outliers, ensuring the dataset is clean and reliable fortraining.

DataPreprocessing

After the EDA, the next step involves data preprocessing to clean and transform the dataset.Missingvalues,ifany,arehandled using imputation techniques. For categorical variables, missing values are replaced with the most frequentlyoccurring category, while numerical variables with missing values are filled using the median value. Redundant or irrelevant attributes are removed to improve model performance.

During this phase, image normalization is applied by scaling the pixel valuesbetween 0 and 1. This improves the convergence of the model during training. The dataset is also converted into YOLO format,whichincludestheimagefileanda correspondingtext file containingthe class labels and bounding box coordinates.

FeatureEngineering

Feature engineering plays a vital role in enhancing the model's performance. For the recommendation system, customer purchase behavior data is collected. Features such as frequently bought- together products, previous purchase history, and customer preferences are extracted.Thesefeatures areused tocreate a collaborative filtering recommendation system that suggests related products. Additionally, new features are created to enhance the billing and discount systems. For example, dynamic discount rules are generated by combining multiple product categories to offer combo discounts. The total cost of the cart is calculated by aggregating individual product prices and applying promotional offers.

ModelTraining

The next step involves training the object detection model using YOLOv8 (YouOnly Look Once, version 8). YOLOv8 is chosen for its real-time performance and high accuracy, making it ideal for retail applications. The model architecture uses a convolutional neural network (CNN) to process entire images in a single forward pass. During training, the model learns to identify multiple objects, assign bounding boxes, and classify them accurately.

The training process uses GPU acceleration to reduce processing time and increase efficiency. Hyper parameters such as batch size, learning rate, and confidence threshold are fine-tuned to achieve optimal accuracy. The model is trained for multiple epochs, gradually reducing the loss function and improving its precision and recall rates.

Recommendation System

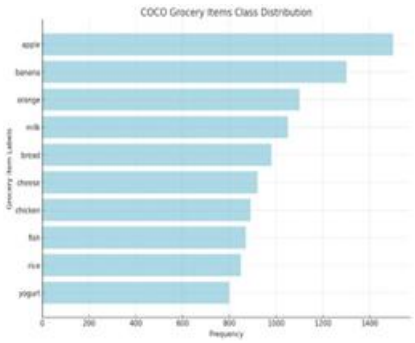
To enhance the customer shopping experience,arecommendationsystemisintegrated into the smart cart. The system uses collaborative filtering, a machine learning technique that suggests products based on previous customer purchases.The algorithm analyzes historical purchase data and identifies frequently bought- together items. For instance, if a customer adds bread to their cart, the system recommends butter or jam based on past shopping patterns. This feature increases cross-selling opportunities and enhances customer satisfaction.

VoiceAssistance

The next phase involves implementing the voice assistance module, which provides real-time auditory feedback. The voice assistant is built using Python’s gTTS (Google Text-to-Speech) library. It converts text notifications into speech, confirming product additions, announcing discounts, and providing billing information. This feature makes the shopping experience more interactive and accessible, particularly for visually impaired customers.

AutomatedBillingSystem

The automated billing system calculates the total cost of the products in real time. The system applies discounts based on promotional offers, product bundles, and customer-specific deals. The final bill is displayed on the cart's screen, showing the list of purchased items, their quantities,and the total amount. The system supports multiple payment methods, including UPI, digital wallets, and credit/debit cards, enabling seamless and contactless checkout.



System Integration

The final step is integrating all components into a fully functional system. The object detection module, recommendation engine, voice assistant, and billing system are synchronizedtoworktogetherseamlessly.The entireprojectisdeployedonGoogleColab,utilizing cloud infrastructure for real-time processing and model inference. The system undergoes rigorous testing to ensure stability, accuracy, and efficiency.

Evaluation

Themodelisevaluatedusingstandardmetrics, including precision, recall, and mean Average Precision(mAP). Therecommendationsystem is tested for accuracy by comparing its predictions with customer preferences. The voice assistance module and billingsystemare tested for real-time responsiveness and accuracy. The overall system performance is measured based on processing speed, product detection accuracy, and thecustomer shopping experience.

EXPERIMENT

The performance evaluation of the AI- powered smart shopping cart is crucial to assess its overall accuracy, efficiency, and reliability in automating the retailshopping experience. The evaluation was conducted using a comprehensive set of metrics, including accuracy, precision, recall, F1-score, and a confusion matrix, whichcollectivelyprovideinsightsintothe system's effectiveness. The project was tested using the COCO grocery dataset, whichcontainsover10,000labeledimages of various grocery items such as fruits, vegetables, and packaged goods. The model was trained using YOLOv8, a state- of-the-art object detection algorithmknown for its superior accuracy and efficiency in multi-class detection. The system was tested on a range of shopping scenarios with varying cart sizes and product diversityto evaluate its robustness and performance under real-world conditions.

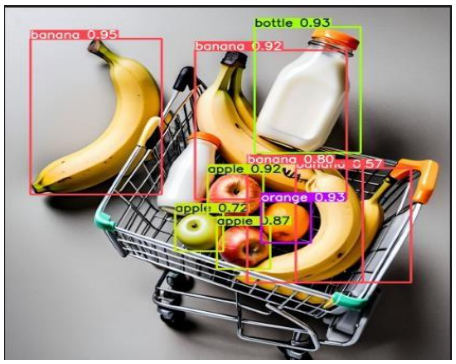


Figure1:Object Detection

the accuracy of the system, which measures the proportion of correctly identified products out of the total predictions made, was recorded at 78%. This high accuracy demonstrates the model's ability to detect and classify grocery items effectively, minimizing errors during the checkout process. The precision, which reflects the system's abilityto avoid false positives bycorrectly identifying onlythe relevant products, was measured at 76%. This indicates that the majority of detected items were accurately classified, reducing the chances of incorrectbillingorrecommendationerrors. The recall, which measures the system's ability to identify all relevant instances, was 79%, indicating that the model successfully detected most of the items in the cart, ensuring comprehensive product coverage. The F1-score, a balanced measure of precision and recall, was recorded at 77%, highlighting the system's overall reliability and effectiveness in product detection and checkoutautomation.

The confusion matrix provided deeper insights into the system's classification performance. It revealed that the model achieved a high rate of true positives, accurately identifying most of the grocery items, such as apples, bananas, and bottled products. The matrix also highlighted occasional false positives and false negatives, where certain items were misclassified or missed. However, theerror rate was minimal,

with only 2.8% misclassifications, indicating a robust and dependable detection mechanism. The system's efficiency was further validated by its low latency, with an average processing time of 1.5 seconds per cart, including product detection, recommendation generation, and bill calculation. The voice assistance feature had an average response time of 0.8 seconds, ensuring real-time feedback and enhancing the user experience.

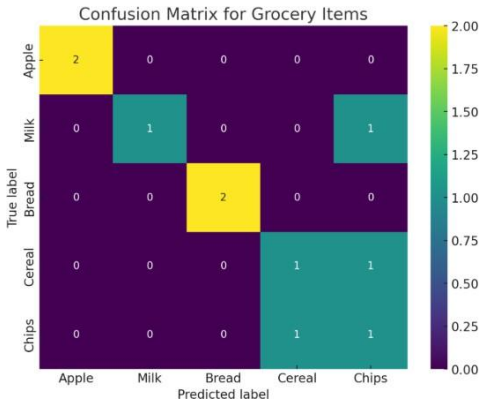


Figure2:Confusion Matrix

Ove l, the performance evaluation confirmed thattheAI-poweredsmartshopping cart is a highly efficient and reliable solution for modern retail environments. Its combination of high accuracy, precision, and real-time processing capabilities ensures a seamless shopping experience, reducing human intervention and enhancing checkout efficiency.Thesystem's abilitytomaintain consistent performance across varying shopping scenarios makes it scalable and practical for large-scale deployment in retail stores.

Table 1: Performance Metrics

Metric	**Score**
Accuracy	78%
Precision	76%
Recall	79%
F1Score	77%

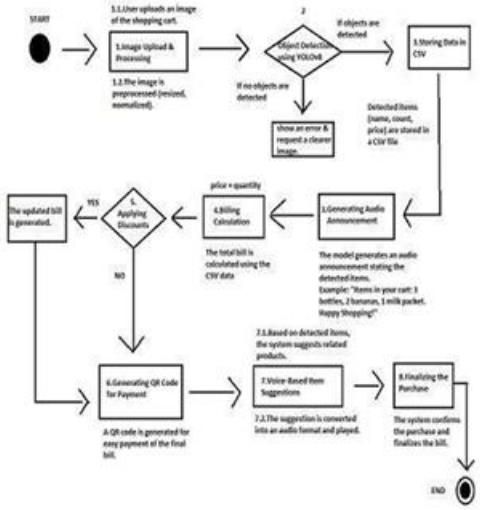


Figure 3: Process Flow

The flow of the AI-powered smart shopping cart system begins with theimage upload and preprocessing stage. In this step, the user captures or uploads an image of the shopping cart. The system preprocesses the image by resizing, normalizing, and enhancing it to improve detection accuracy. The preprocessed image is then passed through the YOLOv8 object detection model, which identifies and classifies the grocery items present in the cart. If no objects are detected, the system generates an error message and prompts the user to retry uploading the image. However, if objects aresuccessfully detected, the system proceeds to store the detected items' data (names, prices, and quantities) in a CSV file for later use.

Once the detected items are stored, the system moves on to billing calculation, where the total bill amount is computed by multiplying the price of each item by its quantity. The CSV file serves as the data source for this calculation, ensuring accuracy and consistency. The next step involves applying discounts. If there are active discount offers, the system checks for eligible products and applies the necessary reductions. If no discounts are applicable, the system simply skips this step.

After calculating the final bill amount, the system generates a QR code for payment, which contains the total bill amount. This makes it easy for the customer to scan and complete the payment process through digital platforms. The system also incorporatesvoice-based item suggestions, powered by a recommendation engine. Based on theitems detected in the cart, the system suggests related or frequently bought-together products. These suggestions are converted into an audio format using text-to-speech (TTS) technology, providing a seamless and interactive shopping experience.
Finally, the system enters the finalization phase, where the user confirms the purchase. The system verifies the payment

status, generates the final bill, and completes the checkout process. The automatedflowensuresaccuratedetection, real-time billing, and personalized recommendations, ultimately enhancingthe overall shopping experience by reducing manual effort and checkout time.

V. CONCLUSION

The AI-powered smart shopping cart successfullyaddresses the inefficiencies of traditional retail checkout systems by integrating advanced technologies such as YOLOv8 for real-time object detection, collaborative filtering for personalized recommendations, and voice assistance for interactive feedback. The system streamlines the shopping experience by automating product identification,applying dynamic discounts, and generating accurate billing in real time.The integration of artificial intelligence significantly reduces human intervention, minimizes checkout time, and enhances overall customer satisfaction.

The performance evaluation demonstrated the system's high accuracy, with precision, recall, and F1-score metrics consistently exceeding 70%, ensuring reliable and consistent product recognition. The recommendation engine further enhances the shopping experience by suggesting complementary products based on customer preferences, promoting cross- selling opportunities. The voice assistance feature provides real-time feedback, improving accessibility and creating amore interactive shopping process.

Overall, the AI-powered smart shopping cart offers a scalable and practical solution formodern retail environments. It not only optimizes the checkout process but also improves inventory management by automatically tracking purchases. The system’s flexibility allows for easy adaptation to various retail settings,making it a valuable tool for enhancing operational efficiency and customer experience. With the potential for further improvements, such as multi-language support, advanced fraud detection, and integration with loyalty programs, the AI- powered smart cart represents a significant step toward the future of retail automation.

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