International Journal of Computer Sciences and Engineering
Vol.**12**, Issue.**10**, pp.**22-25**, October **2024**
ISSN: 2347-2693 (Online)
Available online at: www.ijcseonline.org

Review Article

Exploring the NexGen Billing Cart using IoT and Machine Learning Solutions for Retail Automation

Arpan Shah[1], Avantika Junagade[2*], Aditya Thakare[3], Mansi Patil[4], Prasad Lahare[5]

[1,2,3,4,5]Dept. of Information Technology, Pune Vidyarthi Griha's College of Engineering & S.S.D. Institute of Management, Nashik, MH, India

**Corresponding Author: avantikajunagade2019@gmail.com*

Received: 23/Aug/2024; **Accepted**: 25/Sept/2024; **Published**: 31/Oct/2024. **DOI**: https://doi.org/10.26438/ijcse/v12i10.2225

Abstract: The NexGen Billing Cart project addresses critical challenges in retail, including prolonged billing times and inefficient inventory management, by introducing an automated billing system that leverages IoT and machine learning. Utilizing a Raspberry Pi, a camera module, and YOLO-NAS for object detection, the system identifies and processes items placed in the cart, automating the checkout experience. This solution provides real-time inventory updates and enhances customer experience by streamlining the checkout process, minimizing human error, and reducing labor demands. Experimental results demonstrate high accuracy in item recognition and efficient real-time processing, indicating the model's potential to optimize retail operations. The propose system represents a significant advancement toward seamless and automated retail experiences, providing a scalable and practical solution for inventory control and customer service improvement.

Keywords: Automated Billing, IoT in Retail, Machine Learning, YOLO-NAS, Inventory Management, Retail Automation, Smart Cart, Computer Vision.

1. Introduction

In today's fast-paced retail world, traditional checkout lines often mean longer wait times and can leave customers feeling frustrated. The growing demand for efficiency and convenience has highlighted the need for innovative solutions that can enhance the shopping experience. As retail businesses seek to streamline operations and improve customer engagement, integrating automation technologies has become essential.

The Internet of Things (IoT) and machine learning (ML) play crucial roles in addressing these challenges. IoT enables seamless communication between devices, allowing for real-time data exchange and management. This connectivity enhances inventory tracking and customer interactions, while ML algorithms can analyze consumer behavior and optimize operational processes. Together, these technologies facilitate automated billing systems that not only reduce checkout times but also provide valuable insights into inventory dynamics.

The primary objective of the NexGen Billing Cart project is to develop a smart shopping solution that automates item detection, recognition, and checkout processes. By leveraging IoT and ML technologies, the project aims to create an efficient, user-friendly system that enhances the overall shopping experience while effectively managing inventory in real time.

2. Related Work

In [1], a Smart Trolley system was introduced that utilizes Raspberry Pi and barcode scanners to automate product scanning and billing in shopping malls. This system reduces human intervention by integrating embedded systems and real-time communication, streamlining the checkout process.

An Intelligent Shopping Cart system proposed in [2] incorporates RFID technology and ZigBee communication to automate product identification and billing. As soon as a product with an RFID tag is added or removed from the cart, the system automatically updates the bill. This approach eliminates long queues and enhances customer convenience while also managing inventory in real-time.

The use of RFID for mapping and localization was further explored in [3]. Here, RFID tags attached to objects were used to improve the accuracy of localization for mobile robots and people within indoor environments. By fusing RFID data with laser range finders, the study demonstrated enhanced tracking and localization capabilities.

Additionally, a Low-Cost Intelligent Shopping Cart system was proposed in [4], utilizing RFID tags, ZigBee modules, and infrared sensors for dynamic product localization and automated billing. This system offers a scalable and cost-effective solution for shopping automation while providing real-time product information and inventory updates.

RFID-based systems, such as the Automatic Billing Trolley [5], streamline checkout by detecting products added to the cart and automatically updating the bill. RFID-based systems, such as the Automatic Billing Trolley [5], streamline checkout by detecting products added to the cart and automatically updating the bill. Similarly, the Automatic Shopping Cart System [6] employs ZigBee and RFID for real-time billing updates, reducing queue times. Another innovation, the Smart Trolley Using Automated Billing Interface [7], integrates RFID with an Arduino microcontroller and a web interface to further simplify the billing process.

The convergence of machine learning (ML) and Internet of Things (IoT) technologies has led to significant advancements in both manufacturing and computer vision applications. In a recent study by Jyothi et al. [8], the performance of real-time object detection algorithms, specifically YOLOv8 and Faster R-CNN, is evaluated. Object detection involves the classification and localization of objects within images and videos, a critical area in AI-driven computer vision. YOLOv8 is noted for its efficiency in single-step object detection, contrasting with the two-stage process of Faster R-CNN. The study found YOLOv8 to be more suitable for real-time applications due to its faster processing time and higher Intersection over Union (IoU) scores, which indicate better accuracy in object localization. The research supports YOLOv8's versatility across devices, emphasizing its high speed and accuracy in tasks that require immediate detection, making it highly effective for real-time deployment [8].

Gore and Patil [9] explore the integration of ML and IoT within the manufacturing industry, focusing on how these technologies drive the concept of Industry 4.0. The paper highlights how IoT-connected devices and ML algorithms are instrumental in achieving smart manufacturing processes, with applications like predictive maintenance, real-time process monitoring, and IoT-based security. Anomaly detection in products, for example, is enhanced through ML algorithms that analyze and identify defects in real-time, reducing human error. Predictive maintenance, facilitated by ML, improves machinery uptime by predicting potential failures and servicing needs. This paper also addresses the challenges faced in IoT-ML integration, such as the need for high-quality data, continuous connectivity, and expertise scarcity in these technologies. These challenges underscore the barriers to achieving a fully interconnected Industry 4.0 framework, though the potential benefits suggest a promising future [9].

3. Theory

3.1 System Architecture

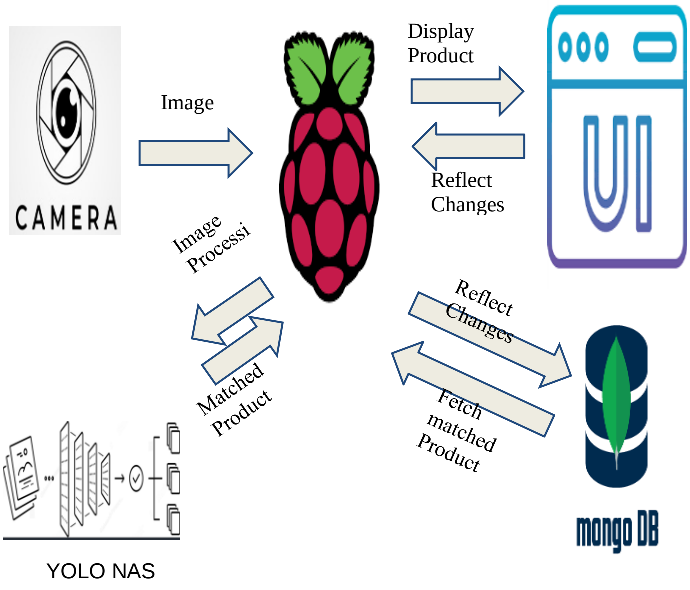

Figure 1: Architecture of System

The *NexGen Billing Cart* integrates Internet of Things (IoT) and machine learning to streamline the retail billing and inventory process. The core architecture comprises a Raspberry Pi microcontroller, a camera module, and a touchscreen display for user interaction. The system leverages YOLO-NAS, a state-of-the-art object detection model, to identify and classify items in real time as they are placed in the cart.

The architecture comprises five main components: a camera module, Raspberry Pi, YOLO-NAS model, MongoDB database, and a user interface (UI).

1. **Camera Module**: The camera captures images of items as they are placed in the cart. These images are then sent to the Raspberry Pi for processing.
2. **Raspberry Pi**: Serving as the core processing unit, the Raspberry Pi receives images from the camera and performs image processing to identify items. It utilizes the YOLO-NAS (You Only Look Once - Neural Architecture Search) model to detect and classify items in real time. Once an item is recognized, the corresponding product information is sent to the database and displayed on the user interface.
3. **YOLO-NAS Model**: YOLO-NAS, an efficient object detection model optimized for edge devices like the Raspberry Pi, analyzes the images captured by the camera to identify items. YOLO-NAS is designed to balance speed and accuracy, making it suitable for real-time item recognition. After identifying an item, the model returns the detected product data to the Raspberry Pi.
4. **MongoDB Database**: MongoDB stores all relevant product information, including item details and stock levels. Once an item is identified by YOLO-NAS, the Raspberry Pi fetches the corresponding product details from the database. Any inventory changes, such as adding or removing items from the cart, are updated in MongoDB, ensuring accurate, real-time stock monitoring.

5. **User Interface (UI)**: The UI provides a display for customers, showing the detected products and their prices. It also reflects changes from the database, including updated inventory counts and the total bill. This real-time feedback keeps the customer informed about the contents and cost of their cart.

Data Flow:
1. The **Camera** captures an image and sends it to the **Raspberry Pi** for processing.
2. The **Raspberry Pi** processes the image using the **YOLO-NAS model**, which identifies the item and then checks the **MongoDB database** for a product match.
3. The matched product details are fetched from MongoDB and displayed on the **UI**.
4. Any inventory changes are automatically updated in MongoDB, and the UI reflects these changes in real-time.

3.2 Flow Chart
The system is initialized to receive input e.i. an Image and begin the billing sequence. The system captures an image of the products in the customer's cart using a camera. After which the captured image is processed by CNN and the system checks if the image matches the product present in the database. If the match is found, then the system fetches the product information from the database and updates the UI to display the product and its price. As the products are added, the system updates the real time bill e.i. The total amount displayed on UI with the identified products and their corresponding information. If the product is removed from the UI, then the system reflects those changes in the backend and updates the real time bill. When the customer is finished adding the product, the system asks if he/she wants to generate the bill. If yes, then System asks for Mobile no. of the customer and provides two options for the payment which are UPI and Pay-at-counter. After the payment process is done the System generates and sends the Bill Invoice via SMS to Customers mobile phone.

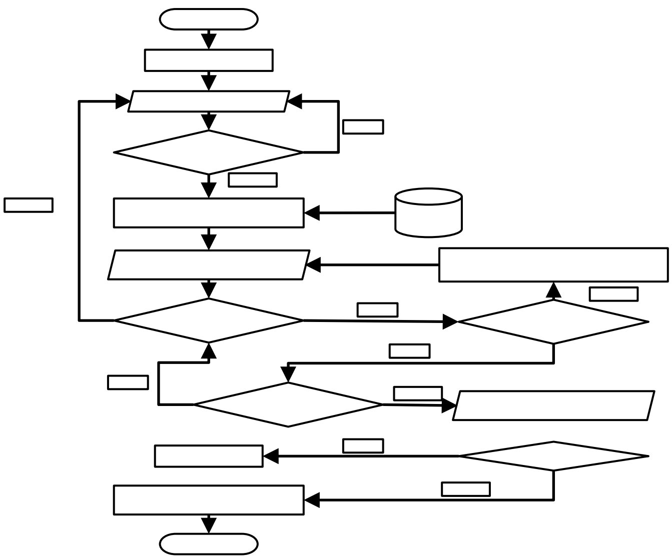

Figure 2: Flow Chart

4. Experimental Procedure

4.1 Object Detection Model: YOLO-NAS
The object detection process is driven by the YOLO-NAS (You Only Look Once - Neural Architecture Search) model, chosen for its ability to balance accuracy and inference speed. YOLO-NAS is optimized for edge devices like the Raspberry Pi, providing rapid item identification even with limited hardware resources. The model uses convolutional neural networks (CNNs) to detect objects within image frames captured by the cart's camera, allowing for high accuracy in object recognition with minimal latency.

Key parameters for the YOLO-NAS model include:
- **Confidence Threshold**: Set to a high value (e.g., 0.7) to reduce false positives.
- **Intersection over Union (IoU)**: Used to calculate the overlap between detected objects and ground truth bounding boxes, aiding in accurate classification.

4.2 Calculation of Detection Accuracy
To validate the performance of the object detection model, we calculate its accuracy using standard metrics:
1. **Precision (P)**: Measures the proportion of correctly identified items out of all detected items.
   Precision=$True\ Positives/(True\ Positives + False\ Positives)$
2. **Recall (R)**: Reflects the proportion of correctly identified items out of all items actually present in the frame.
   Recall=$True\ Positives/(True\ Positives + False\ Negatives)$
   F1 Score: Provides a balanced measure of precision and recall, which is essential for evaluating the detection accuracy.
   F1 = $2 \times (Precision \times Recall/Precision + Recall)$

4.3 Real-Time Processing and Latency
Latency is a critical factor in user experience, as any delays in item recognition can impact the flow of customer checkout. The processing time (TprocessT_{process}Tprocess) for each frame can be calculated as:
Tprocess= $Tcapture + Tdetect + Tdisplay$
where,
- Tcapture: Time for capturing an image frame,
- Tdetect: YOLO-NAS model inference time,
- Tdisplay: Time to display the detected item on the touchscreen.

Optimizing these components is essential to maintaining a smooth, real-time experience in the retail setting.

5. Conclusion

This paper presents the design and potential of the NexGen Billing Cart, a conceptual smart shopping solution utilizing IoT and machine learning to automate retail processes. By integrating a Raspberry Pi and camera module for item detection, the system aims to reduce checkout times and billing errors. While the solution is scalable and cost-effective, further research and development are needed to implement the system, validate its performance in real-world scenarios, and address challenges in item recognition and seamless integration across diverse retail environments..

Data Availability

The data used in the “NexGen Billing Cart” project includes product images and item metadata required for training and testing the YOLO-NAS model. These data were obtained specifically for this project and include item categories typically found in retail environments. Due to privacy and proprietary restrictions, the data are not publicly available. However, interested researchers may request access by contacting the authors, subject to institutional and data-sharing agreements.

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this paper.

Authors’ Contributions

Author-1 wrote the first draft of the manuscript, Author-2 researched literature and conceived the study, Author-3 gathered the information about the idea and did data analysis, Author-4 wrote the second draft of the manuscript and Author -5 guided other authors throughout the process of drafting the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Acknowledgements

The authors would like to thank Pune Vidyarthi Griha's College of Engineering, Nashik, for providing resources and support throughout the development of the “NexGen Billing Cart” project. We extend our gratitude to our team members for their collaborative effort in making this project successful. Additionally, we acknowledge the mentors and faculty who guided us for the encouragement to innovate in the field of retail automation.

References

[1] S. Shailesh, P.S. Deb, R. Chauhan, and V. Tyagi, “Smart Trolley.” *In 2021 International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)*, IEEE, pp. 242-245, March 2021.

[2] R. Kumar, K. Gopalakrishna, and K. Ramesha, “Intelligent shopping cart.” *International Journal of Engineering Science and Innovative Technology*, vol. 2, no. 4, pp.499-507, 2013.

[3] D. Hahnel, W. Burgard, D. Fox, K. Fishkin and M. Philipose, "Mapping and localization with RFID technology", *Proc. IEEE Int. Conf Robot. Autom*, pp. 1015 - 1020 2004.

[4] J. Suryaprasad, BO Praveen Kumar, D. Roopa, and A. K. Arjun, "A novel low-cost intelligent shopping cart." *In 2011 IEEE 2nd International Conference on Networked Embedded Systems for Enterprise Applications*, IEEE, pp. 1-4, 2011.

[5] P. A, V. A, N. K. C, S. R and K. K, "Automatic Billing Trolley for an Enhanced Supermarket using RFID," *2023 7th International Conference on Computing Methodologies and Communication (ICCMC)*, Erode, India, 2023, pp. 840-844, doi: 10.1109/ICCMC56507.2023.10083555.

[6] N. Sharma, A. Gupta, S. K. Gupta, R. Raman Chandan, A. Srivastava and P. Yadav, "Automatic Shopping Cart System using ZigBee Technology and RFID Module," *2021 IEEE International Conference on Technology, Research, and Innovation for Betterment of Society (TRIBES)*, Raipur, India, 2021, pp. 1-6, doi: 10.1109/TRIBES52498.2021.9751668.

[7] R. Singh, K. N. Rao, R. Naik, Geetha, K. Anjali and P. Vineeth, "Smart Trolley Using Automated Billing Interface," *2022 International Conference on Advancements in Smart, Secure and Intelligent Computing (ASSIC)*, Bhubaneswar, India, 2022, pp. 1-5, doi: 10.1109/ASSIC55218.2022.10088393.

[8] B. S. Jyothi, C. S. D. Abhinaya, B. Lahari, C. D. Priya, D. Anjali, and B. S. Navya, “Performance Evaluation on Real-time Object Detection Using DL Techniques,” *International Journal of Computer Sciences and Engineering*, vol. 12, no. 4, pp. 75–80, Apr. 2024.

[9] R. R. Gore and J. D. Patil, “A Study of Machine Learning and IoT in Manufacturing Industries,” *International Journal of Computer Sciences and Engineering*, vol. 7, Special Issue, pp. 7–11, Mar. 2019.

[10] Komal Machhirke, Priyanka Goche, Rupali Rathod, Rinku Petkar, Manohar Golait , “ A New Technology of Smart Shopping Cart using RFID and ZIGBEE”, IJRIT CC, vol. 5, no. 2, pp. 256 –259, Feb. 2017.

[11] N.S. Megana, “Design and Implementation of a Smart Shopping Cart by RFID Technology.” *Asian Institute of Technology School of Engineering and Technology*, Thailand, 2018.

AUTHORS PROFILE

Arpan A. Shah, Bachelor of Engineering Student Department of Information Technology, Pune Vidyarthi Griha's College of Engineering & S.S.D. Institute of Management, Nashik

Avantika S. Junagade, Bachelor of Engineering Student Department of Information Technology, Pune Vidyarthi Griha's College of Engineering & S.S.D. Institute of Management, Nashik

Aditya V. Thakare, Bachelor of Engineering Student Department of Information Technology, Pune Vidyarthi Griha's College of Engineering & S.S.D. Institute of Management, Nashik

Mansi V. Patil, Bachelor of Engineering Student Department of Information Technology, Pune Vidyarthi Griha's College of Engineering & S.S.D. Institute of Management, Nashik

Prasad A. Lahare, working as Professor in Department of Information Technology at Pune Vidyarthi Griha's College of Engineering & S.S.D. Institute of Management, Nashik

