# Development of Shopping Bot

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***Abstract***

*This paper presents the development and evaluation of a novel shopping bot prototype designed to revolutionize retail operations. The growing reliance on manual retrieval processes in traditional retail environments necessitates advancements that enhance efficiency and customer satisfaction. This project addresses this challenge by introducing a shopping bot that integrates robotics (line-following, infrared sensors, robotic arm), electronics (high-resolution camera), and web technologies. The resulting prototype demonstrates autonomous navigation within a controlled environment, efficient item identification using QR codes, and precise manipulation of lightweight items. This successful development underscores the feasibility of such technologies for automating in-store shopping processes. Version X lays the groundwork for future iterations exploring functionalities like obstacle avoidance, user interaction via a web interface, and broader object recognition capabilities. Overall, the project highlights the potential for shopping assistance technologies to significantly improve retail efficiency, accuracy, and customer experience.*

**Key Words:** Robotics, Shopping bot, Autonomous navigation, QR code recognition

## 1. INTRODUCTION

The contemporary retail landscape is undergoing a shift towards increased customer convenience and operational efficiency. Traditional methods of product retrieval and customer assistance, which often involve manual processes, can lead to extended wait times and a less-than-optimal shopping experience. Customers are increasingly seeking methods to navigate stores, locate desired items with greater speed, and ease [1]. This pursuit of efficiency extends to retailers as well, as manual product retrieval tasks can consume valuable staff resources that could be better utilized for providing personalized customer service [11].

This paper presents a potential solution to these identified challenges: the development of an autonomous shopping bot designed to streamline in-store operations and enhance customer satisfaction. This QR code-guided shopping bot leverages a combination of hardware and software components to navigate retail environments. Customers can interact with the bot through strategically placed QR codes, which provide product information and guide the bot to locate and retrieve desired items. This novel approach has the potential to revolutionize in-store shopping by automating product retrieval tasks and freeing up staff to provide a more personalized customer service experience.

The following sections of this paper will explore the limitations of traditional retail operations in detail, outlining the potential impact on customer experience. This paper presents a detailed examination of the design and development of the proposed QR code-guided shopping bot, exploring the hardware and software components that enable its functionality. Testing results are presented, showcasing the bot's performance in a real-world setting. Finally, a discussion will be presented on the broader implications of this technology,

considering its potential benefits and limitations for the future of retail.

## 2. PROBLEM DEFINITION

Modern retail environments, despite their familiarity, struggle to meet the ever-evolving demands of today's fast-paced consumer. A key challenge lies in extended wait times for assistance, particularly during peak shopping hours. A 2022 study by the National Retail Federation revealed that 73% of customers abandon purchases due to long wait times (National Retail Federation [NRF], 2022). This, coupled with the time-consuming process of manually locating products in large stores for both customers and staff, negatively impacts the entire shopping experience.

Further hindering efficiency, a 2022 study by IBM found that manual product retrieval processes can consume up to 50% of a staff member's time (IBM, 2022). This leaves staff with limited availability to provide personalized customer service and in-depth product knowledge, ultimately leading to customer frustration. A 2023 study by PwC found that 75% of customers who experience frustration during their shopping trip are less likely to return to that store (PwC, 2023). The need for innovative solutions in retail becomes clear. By adopting in-store automation technologies, potential solutions emerge to address these challenges and improve efficiency across the board.

## 3. METHODOLOGY

The development of the autonomous shopping bot utilized a structured, five-phase methodology. The initial phase involved a comprehensive review of existing literature and established solutions in the field of autonomous shopping bots. This review aimed to identify design principles, control algorithms, and potential challenges associated with similar projects. Subsequently, a detailed prototype specification document was developed based on the findings from the literature review and the overall project goals. This document outlined the desired functionalities, performance requirements, and physical constraints of the shopping bot.

The third phase focused on design exploration and selection. Various design concepts were explored, considering factors such as navigation approach (line following vs. other methods), product retrieval mechanisms, user interaction methods, and overall system architecture. Following a thorough evaluation and analysis process, a single, feasible design was chosen for further development.

The fourth phase involved the integration of electronic components and the development of a web application. The selection and integration of various electronic components necessary for the bot's operation were undertaken. This included the microcontroller (Raspberry Pi), motor driver (L293), sensors (IR sensors, webcam), and any other necessary hardware. Additionally, a separate web application was developed and hosted to facilitate customer interaction and product selection.

Finally, the chosen design was translated into a physical prototype through fabrication processes. Following fabrication, the bot underwent comprehensive testing and refinement procedures. These procedures evaluated the effectiveness of the line following system, QR code scanning capabilities, product retrieval and overall system performance. A concluding demonstration showcased the completed prototype's functionalities and potential applications. This structured methodology ensured a well-defined development process, informed design choices, and a final prototype that met the project's objectives.

### 3.1 Materials:

- **Chassis:** A 5.5 mm thick sheet of hard cardboard was utilized as the primary structural material for the bot. This material selection balanced weight considerations with adequate rigidity for stable operation.
- **Drive System:** A four-wheeled rear-wheel drive (RWD) configuration was implemented for bot movement. This design provided efficient maneuverability within the designated operating environment.
- **Navigation Sensors:** Two infrared (IR) sensors were positioned at the front of the bot to facilitate line following navigation. An additional IR sensor was placed on the side of the bot to detect designated stopping points.
- **Microcontroller:** A Raspberry Pi 4 B model served as the central processing unit for the bot. This powerful and versatile microcontroller offered the necessary computational resources for control algorithms and sensor data processing.
- **Motor Driver:** An L293 motor driver was employed to interface with and control the two

driving wheels of the bot. This driver enabled precise control over motor speed and direction.

- **User Interface:** An LCD display was positioned on the left side of the bot for passive visual communication. This display provided basic operational status information to users.
- **Web Application Development:** A separate web application was developed and hosted to facilitate customer interaction and product selection. This application played a crucial role in user experience and product management. The web application was developed using Flask, a lightweight Python web framework. Flask provided a flexible and efficient foundation for building the application's functionalities.
- **Product Identification:** A webcam was mounted on the right side of the bot for QR code scanning purposes. This component enabled the bot to identify specific products on shelves based on pre-encoded QR code information.
- **QR Code Scanning Library:** PyZBar, a Python library specializing in QR code decoding, was utilized to process data captured by the webcam. This library facilitated the extraction of product identification information from QR codes.
- **Product Retrieval Mechanism:** The bot was designed to retrieve products, by a two-jaw gripper grasping mechanism

**Methods:**

- **Line Following Algorithm:** A line following algorithm was implemented to control the bot's movement and maintain its position on designated paths within the store environment. This algorithm relied on sensor data from the IR sensors to guide the bot's steering and navigation.

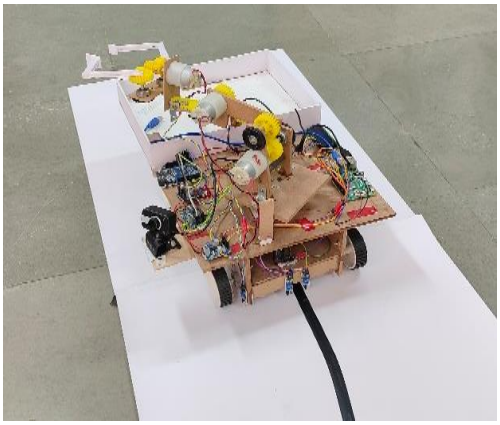

Figure 1: IR sensor placement for line following mechanism

- **QR Code Decoding:** PyZBar library functions were employed to decode data captured by the webcam from QR codes placed on shelves. The decoded data was then compared against a product list transmitted from the web application.
- **Control Software Development:** The control software for the bot was written in Python, leveraging the capabilities of the Raspberry Pi platform. This software integrated sensor data processing, navigation algorithms, QR code decoding functions, and communication protocols with the web application.
- **Testing and Refinement:** Following fabrication, the bot underwent comprehensive testing procedures. These procedures evaluated the effectiveness of the line following system, QR code scanning capabilities, product retrieval mechanism and overall system performance. Based on test results, the software and hardware configurations were iteratively refined to optimize performance and address any identified shortcomings.

## 4. Results

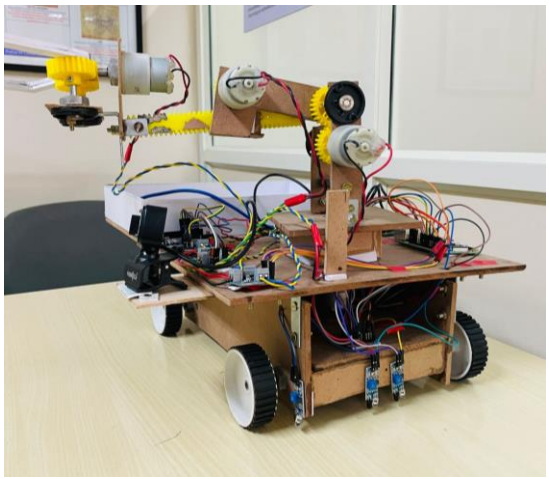

Figure 2: The Shopping Bot

Testing the autonomous shopping bot yielded valuable insights. The interactive website was very responsive and made it easier for the customer to place an order and receive bill at checkout without any hassle of waiting in long queue. The bot excelled at navigating paths, handling both straight and curved lines. This success can be measured through metrics like deviation from the path or test run completion rates.

The QR code scanning system worked well in normal and well-lit environments, but struggled in low light. It functioned best when the QR code was positioned between 25 cm and 35 cm from the camera, aligning well with the ideal line following path of 30 cm. Higher-quality cameras could extend the scanning range. In this prototype, QR codes needed to be at least 180 mm from the ground for the camera to see them. This measurement can vary depending on camera angle and mobility.

While the bot's capacity (7kg) was sufficient, the current design limited retrieval to lightweight objects due to the grasping mechanism's weakness and the need for improved robot arm control code for more precise movements.

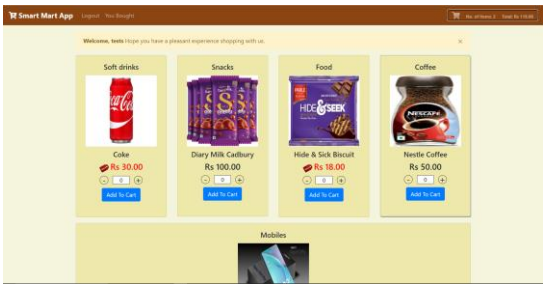


Figure 3: Customer Interactive Website

**Discussion**

The bot's ability to navigate and identify products effectively paves the way for future applications in retail automation. However, limitations in QR code scanning under low light and grasping mechanism strength for heavier objects require improvement. Optimizing QR code scanning distance and exploring higher-quality cameras could enhance product identification. Additionally, replacing DC motors with servo motors and refining the robot arm control code are crucial for more versatile product retrieval. By addressing these limitations, the autonomous shopping bot has the potential to become a valuable tool in the retail industry, improving customer experience and operational efficiency.

## 5. CONCLUSION

This project successfully demonstrated the potential of an autonomous shopping bot for navigating retail environments and identifying products. The bot's ability to follow both straight and curved paths efficiently, along with its accurate QR code scanning under normal lighting conditions, lays the groundwork for future automation within the retail sector. The website plays an integral part as it acts as connecting bridge between the customer and the bot, further improvements in the UI and features of the website will enhancement the user experience and satisfaction.

While the project identified limitations in QR code scanning under low-light conditions and the grasping mechanism's capacity for handling heavier objects, it also highlighted clear pathways for improvement. Optimizing the QR code scanning distance based on the line following path and exploring higher-quality cameras offer promising solutions for enhanced product identification. Additionally, replacing the DC motors with servo motors and refining the robot arm control code hold significant potential for achieving more versatile product retrieval. Addressing these limitations will pave the way for the autonomous shopping bot to become a valuable tool in the retail industry, improving both customer experience and operational efficiency.

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