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Final Project

More Than Just a Customer

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Acknowledgment

We extend our deepest and most heartfelt gratitude to everyone who contributed to the successful development and implementation of the "More Than Just a Customer" project. This milestone could not have been achieved without the collective effort, continuous encouragement, and steadfast support of numerous individuals who stood by us throughout this journey.

At the forefront of this accomplishment, we are especially honored to express our sincere appreciation to our esteemed supervisor, **Mr. Mahmoud Assad**, whose exceptional guidance, technical insight, and unwavering mentorship played a pivotal role in shaping the vision and execution of our hardware-based project. His thoughtful feedback, constant motivation, and belief in our abilities were vital in overcoming engineering challenges and maintaining a clear focus on our goals. Mr. Assad's professionalism, patience, and dedication served as an enduring source of inspiration, and for that, we are truly grateful.

We would also like to extend our deepest thanks to the distinguished faculty members of the **Computer Engineering Department**, whose dedication to fostering a culture of innovation and hands-on learning helped provide the solid academic and technical foundation upon which our system was built. Their continued support, constructive critique, and encouragement empowered us to explore new ideas, think critically, and strive for the highest standards in both design and functionality.

We are also immensely grateful to our colleagues, peers, and friends for their collaborative spirit and shared knowledge, which enriched our development process and strengthened our teamwork. Each thoughtful suggestion and word of encouragement helped bring us closer to our goal.

To our families, your constant emotional support, patience, and faith in us throughout this endeavor have been invaluable. Your sacrifices, understanding, and motivation carried us through long nights in the lab, moments of frustration, and periods of uncertainty. You were our anchor, and we owe you a great debt of gratitude.

In conclusion, the completion of the **"More Than Just a Customer"** system is more than just a technical achievement—it is a reflection of the collective passion, commitment, and shared vision of a community that believes in the power of technology to create a more inclusive and accessible world. We are incredibly proud of what has been accomplished and are confident that this project will serve as a valuable tool in empowering individuals with disabilities to shop independently and safely.

Abstract

"More Than Just a Customer" : Enhancing Safe and Independent Shopping for People with Disabilities

This project introduces "More Than Just a Customer", an integrated smart solution designed to assist people with disabilities and the elderly during their shopping experience. The system features a motorized wheelchair equipped with ergonomic adjustments and an attachable smart device aimed at providing a safer and more informed shopping process.

The wheelchair offers enhanced comfort and functionality by allowing rotation of ±90 degrees to facilitate easy access to store shelves. It also includes a height-adjustable seat to help users reach products placed at different levels. Movement and rotation are controlled via a joystick and dedicated buttons, ensuring intuitive and smooth navigation.

The attachable smart device mechanically mounts on the wheelchair and scans product barcodes, delivering real-time information to the user. It alerts if products are religiously prohibited, or subject to ethical boycotts.

"More Than Just a Customer" aims to empower individuals with disabilities to shop independently and safely while respecting their personal, religious, and health-related preferences.

Contents

Chapter 1

Introduction

1.1 Background

For many of us, a quick trip to the grocery store is a simple, even mundane, part of life. But for individuals with mobility or visual impairments, it can be a daunting challenge. Navigating crowded aisles, reaching for items on high or low shelves, and simply reading a product label can turn an errand into an exhausting ordeal. This project is born from a simple question: how can technology restore independence and dignity to this essential everyday task?

Over the last decade, smart wheelchairs have emerged as incredible tools for mobility, using sensors and smart navigation to help users avoid obstacles and move safely [1], [2]. They are a testament to how engineering can grant physical freedom. Research in assistive technologies has made significant strides in electronic travel aids for navigation and ambient assisted living systems designed to help the elderly maintain independence [3], [4]. But while these systems excel at providing mobility and environmental control, they often overlook the nuanced needs of specific daily activities.

True independence is more than just freedom of movement; it's also about making your own choices. Imagine being unable to check if a product aligns with your deeply held religious beliefs, or if it comes from a company you ethically object to. For many, this isn't just an inconvenience—it's a source of anxiety and a barrier to living independently. Current technology often stops at physical assistance, leaving a critical gap in helping users make informed personal decisions once they have reached their destination.

"More Than Just a Customer" seeks to bridge that gap. We started with the foundation of a smart wheelchair but asked how we could make it more helpful in a store. We added the ability for the chair to gently turn and adjust its height, not just to navigate, but to help someone reach that box of pasta or that can of beans on their own.

Most importantly, we added a simple scanner. A tool that empowers the user to know exactly what they are buying. With a simple beep, it answers the personal questions that matter: "Is this product halal or haram?" or "Is this brand one I choose to boycott?" This information is given through voice and screen, ensuring it's accessible to all.

This project is more than hardware and software; it's about empathy. It’s about ensuring that everyone has the tools they need to participate fully in their community, make their own choices, and experience the simple joy of shopping for themselves, with confidence and peace of mind.

1.2 Objectives & Motivation

Motivation

Our primary motivation is to empower individuals with disabilities and the elderly by transforming a routine activity—grocery shopping—into an accessible, independent, and dignified experience. We aim to:

- **Support people with disabilities in shopping** by addressing the physical challenges of navigating stores and reaching products.
- **Enable ethical and informed consumer choices** by providing immediate feedback on a product's religious permissibility (Halal/Haram) and ethical status (Boycott/Non-Boycott).
- **Combine advanced mobility assistance with smart scanning technology** into a single, unified system that supports the user from navigation to purchase decision.

Objectives

The main goal of this project is to design and build an integrated smart system based on a motorized wheelchair that enhances safe and independent shopping. This system will provide users with both the physical capability to access products and the information needed to make choices that respect their health, religious, and ethical values.

The specific objectives of the project are:

- **Design and build an ergonomic smart wheelchair** featuring a joystick for intuitive movement, a ±90-degree rotation capability for easier shelf access, and a height-adjustable seat to reach products at different levels.
- **Integrate an attachable smart scanning device** that can read product barcodes to detect and retrieve key product information.
- **Develop a product management system** that classifies products based on their status (e.g., religiously prohibited, ethically boycotted, expired) and links to a database for real-time information.
- **Provide clear multi-modal (audio and visual) feedback** to the user on the product's price, expiration date, and ethical status, ensuring the system is accessible for users with visual impairments.

1.3 Overview

This report walks through our journey of creating the "More Than Just a Customer" system. Here's a roadmap of what's ahead:

- **Chapter 2: Background & Related Work**
  We'll explore existing technologies in smart wheelchairs and assistive shopping tools that inspired our project.
- **Chapter 3: Methodology**
  This chapter breaks down how we built the system—covering both the hardware and software sides of our integrated wheelchair and scanner device.
- **Chapter 4: Results**
  Here we share the outcomes of our testing, showing how the system performed in real-world scenarios.
- **Chapter 5: Discussion**
  We reflect on what worked, what didn't, and what these results mean for the future of assistive shopping technology.
- **Chapter 6: Conclusion & Future Work**
  We wrap up with key takeaways and ideas for how this project could be improved or expanded down the road.

Chapter 2

Theoretical Background & Related Works

This chapter explores the existing ideas and inventions that paved the way for our project. We'll look at the current landscape of assistive technology, from smart wheelchairs that help people move to smart carts that help them shop, to understand where our system, "More Than Just a Customer," fits in.

The journey to create better assistive tools is all about understanding the daily challenges people face and applying technology creatively to solve them. Researchers have long focused on smart wheelchairs, aiming to give users more independence and safety.

A significant challenge has been making this technology affordable and accessible to everyone. For example, researchers have designed low-cost smart wheelchairs specifically for use in developing countries, proving that effective mobility solutions don't have to be prohibitively expensive [5]. A key part of making these systems user-friendly is finding intuitive ways to control them. Beyond simple joysticks, studies have successfully implemented voice recognition and gesture control, allowing users to navigate their chairs with simple spoken commands or hand movements [6].

But independence isn't just about moving around—it's about being able to complete life's essential tasks. Grocery shopping, a routine activity for many, presents a huge set of challenges: navigating narrow aisles, reaching high or low shelves, and reading product labels.

This is where the concept of the smart shopping cart comes in. Some innovative projects have focused on creating "vision-based" smart carts that can help visually impaired shoppers navigate a store and identify products using cameras and sensors [7]. Others have developed entire smart environments within stores to guide visually impaired users to the items they need [8].

However, a gap remains. These solutions often exist in separate worlds: one for mobility (smart wheelchairs) and another for information (smart carts). What if we could bridge that gap? What if a person's mobility device was also their smart shopping assistant?

Our project, "More Than Just a Customer," was inspired by this very question. We saw an opportunity to create a more integrated solution. Instead of requiring a user to transfer to a separate smart cart, we designed a system that brings the smart cart's capabilities directly onto an enhanced smart wheelchair. Our work builds upon the foundation of affordable mobility [5] and intuitive control [6], but combines it with the product-scanning of smart carts [7, 8]. We aim to create a seamless experience that supports a person from the moment they enter the store until they check out, helping them not just move, but also make informed choices about what they buy.

Chapter 3

Methodology

In this section, we provide a detailed explanation of the methodology as following :

3.1 Smart Scanner:

3.1.1 Hardware Components

1- ESP32 (Main Controller & Web Server)

The ESP32 microcontroller serves as the central processing unit for the smart scanner module. Its selection was driven by the requirement for a device capable of robust wireless communication, sufficient processing power, and versatile input/output capabilities—all within a compact and energy-efficient form factor.

The core functions managed by the ESP32 in our system are:

- **Hardware Control**: It directly interfaces with and controls the barcode scanner hardware as the primary input method. Additionally, it manages output components including the LCD screen and speaker, which provide real-time user feedback. This integrated control enables the device to initiate scans, receive decoded data, and deliver multi-modal responses.

- **Data Processing**: It processes the scanned QR/barcode data, which serves as a key to query the product database.

- **Web Server Hosting**: A critical feature of our implementation is the ESP32's ability to host a lightweight wireless web server. This creates a local access point, allowing an administrator to connect a smartphone or laptop directly to the device. Through this intuitive web panel, authorized users can dynamically add, edit, delete, and update product information in the local database in real-time. This ensures the system's product status alerts (e.g., halal, haram, boycotted) are always current without requiring physical access to the hardware or a complex backend infrastructure.

The ESP32 is exceptionally well-suited for this application. Its integrated Wi-Fi support enables the web server functionality and allows for potential future cloud connectivity. The dual-core processor provides the necessary performance to handle the concurrent tasks of hardware control, data processing, and network communication seamlessly. Furthermore, its extensive GPIO pins facilitate easy connection to various peripherals, making it an ideal, all-in-one solution for embedding intelligence into our smart scanner module.

Figure 1 : ESP32

2- Scanner / Barcode Reader

The barcode reader serves as the primary input device for the smart scanner module, functioning as the critical link between the physical product and the digital information system. This component is responsible for capturing and decoding the unique barcode or QR code present on product packaging.

The core functions of the barcode reader in our system are:

- **Product Identification**: It optically scans the standardized barcode, translating the visual pattern into a unique digital identifier (e.g., a GTIN number).
- **Data Acquisition**: This decoded numerical string is instantly transmitted to the ESP32 controller, which uses it as a key to query the product database.
- **System Trigger**: The act of a successful scan initiates the entire feedback process, making the scanner the essential trigger for the system's core functionality.

Integrated seamlessly with the ESP32, the scanner provides a reliable and efficient method for users to identify items. Its accuracy and speed are fundamental to creating a smooth and responsive user experience, ensuring that the subsequent steps—database lookup and multi-modal feedback—are based on correct product information. This allows the system to deliver immediate and relevant information about the product's status, price, and other essential details.

Figure 2: Scanner / Barcode Reader

3- LCD Display

The LCD (Liquid Crystal Display) serves as the primary visual interface of the smart scanner module. It provides users with clear, real-time feedback by displaying product status regarding religious permissibility (Halal/Haram) and ethical standing (Boycotted/Not Boycotted). Controlled directly by the ESP32, the LCD ensures that users receive persistent, accessible visual confirmation of product status, making the system usable for those who may prefer or require visual output.

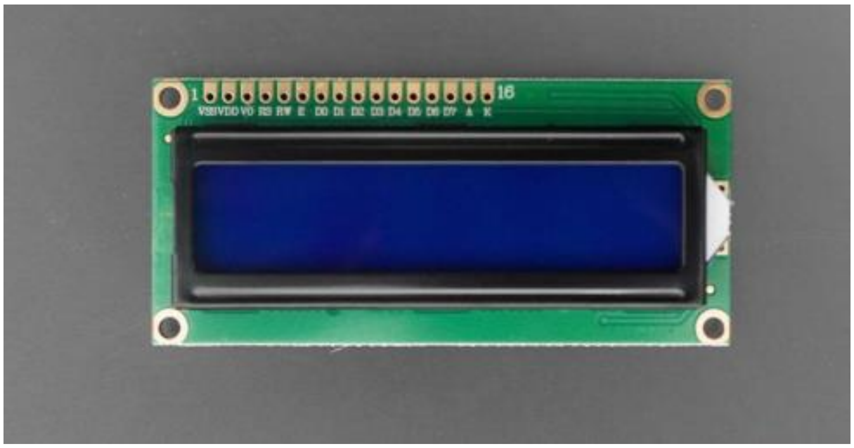

Figure 3: LCD Display

4- DFPlayer Mini + SD Card

The DFPlayer Mini module, combined with a microSD card, functions as the audio storage and playback unit of the system. It stores pre-recorded audio files corresponding to various product status messages (“Allowed” or “Not Allowed”). Upon instruction from the ESP32, it plays the appropriate audio feedback through the connected speaker, providing an essential auditory dimension to the user experience, particularly for those with visual impairments.

Figure 4: DFPlayer Mini

5- Speaker

The speaker acts as the primary output for audible feedback. It works in conjunction with the DFPlayer Mini to deliver clear, intelligible voice messages and alert tones to the user. This component is critical for ensuring the system is accessible, offering immediate verbal confirmation of scan results and product status without requiring the user to view the screen.

Figure 5: Speaker

6- Buzzer

A buzzer is incorporated into the system to provide immediate, distinctive alert tones for urgent or warning notifications. Specifically, it emits sound cues to signal when a scanned product is classified as Haram or Boycotted, offering an additional layer of prompt feedback that enhances user awareness and decision-making.

Figure 6: Buzzer

7- Power Supply (Micro USB)

The system is powered via a Micro USB connection, supplying stable and regulated power to the ESP32 and all peripheral components, including the scanner, LCD, DFPlayer, speaker, and buzzer. This design ensures safe, reliable operation and simplifies recharging or continuous power delivery during use.

Figure 7: Micro USB

3.1.2 Web-Based Product Management Interface

A critical software component hosted directly on the ESP32 is a dynamic web server that provides a user-friendly interface for managing the product database. This interface allows an administrator to intuitively define and update the ethical and religious status of products in real-time, ensuring the system's feedback is always accurate and current.

The core functionality of this web interface includes:

- **Product Addition**: Authorized users can add new products to the database by entering the product's barcode number and manually setting its status (e.g., Halal, Haram, Boycotted, Not Boycotted). This instantly makes the product recognizable by the scanner.
- **Product Status Update**: The status of any existing product can be modified at any time. This allows for quick adjustments based on new information or changing ethical guidelines, ensuring the user always receives the most up-to-date advice.
- **Product Deletion**: Products can be removed from the database if they are no longer relevant or available.

Implementation and Access: The ESP32 generates its own wireless access point. An administrator connects a device (e.g., a smartphone or laptop) to this network and navigates to a simple IP address in a web browser. This brings up the clean, form-based management panel, making database maintenance a seamless process without the need for physical hardware access or complex software tools. This self-contained design emphasizes the system's practicality and ease of use.

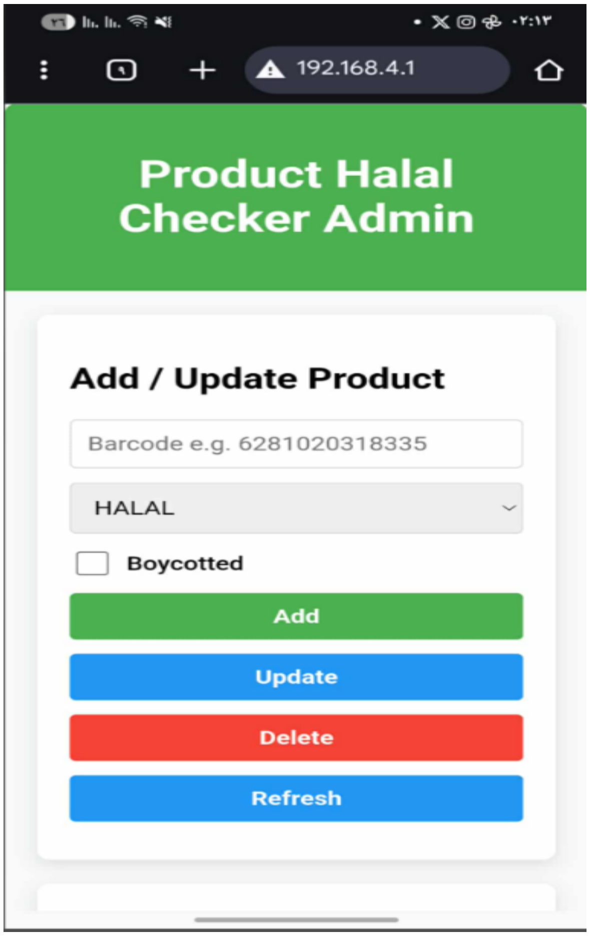

Figure 8: Operations on Products

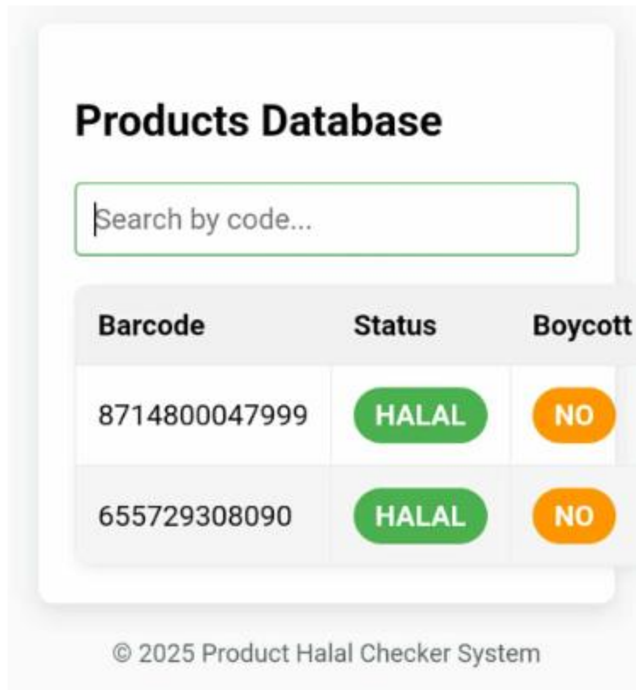

Figure 9: Products Table

3.1.3 Hardware Implementation

3.1.3.1 System Overview

We designed the smart scanner to be simple, accessible, and user-friendly. Instead of a complex technical appearance, we focused on creating a clean interface that feels intuitive and approachable. The entire electronic system is housed in a sturdy carton enclosure, making it both lightweight and cost-effective while providing adequate protection for the components.

From the user's perspective, the device appears straightforward and easy to use. Only three main elements are visible and accessible:

- **The Barcode Scanner**: Positioned for comfortable handling, this is where users interact with products.
- **The LCD Display**: Clearly shows product information and status in an easy-to-read format.
- **The Speaker**: Provides clear audio feedback about product status.

We have intentionally hidden all complex wiring and internal components (including the ESP32, DFPlayer Mini, and buzzer) within the enclosure to avoid overwhelming users with technical details. The only visible connections are one discreet micro-USB port on the side - for power to keep the device running, and for programming updates when needed.

This simple, three-component design approach ensures that users can focus on what matters most: independently scanning products and receiving clear information without confusion or technical barriers. The familiar carton material and clean layout make the technology feel accessible and comfortable to use in everyday shopping situations.

Figure 10: Smart Scanner Front View

3.1.3.2 System Workflow

The true strength of our system lies in its dynamic adaptability and real-world practicality. The seamless interaction between the web-based management interface and immediate user feedback creates a powerful tool that extends far beyond basic product scanning. The following workflow demonstrates this through a practical example, highlighting the system's flexibility and real-world benefits.

System Operation Overview

The user begins by positioning a product so its barcode is visible to the scanner. The device automatically reads the barcode and transmits the numerical code to the ESP32 microcontroller. The ESP32 then queries its internal database to retrieve the product's status and triggers the appropriate output response through the LCD display, speaker, and buzzer.

a) Preparing Sample Products

To demonstrate the system's capabilities, we prepared four sample products representing different ethical and religious categories, as shown in Figure 11.

Figure 11: Sample Products

The initial database configuration recognized the first three products with distinct status classifications, illustrated in Figure 12.

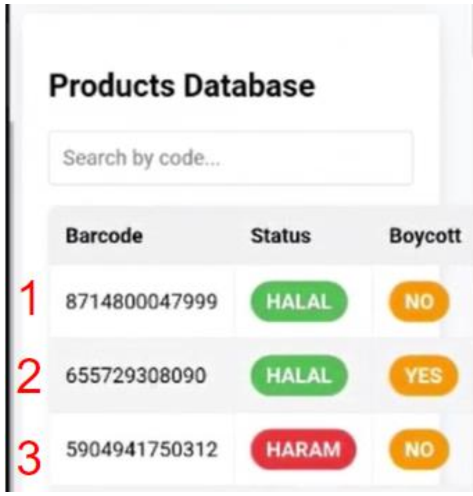

Figure 12: Initial Products Database

b) The First Product Sample

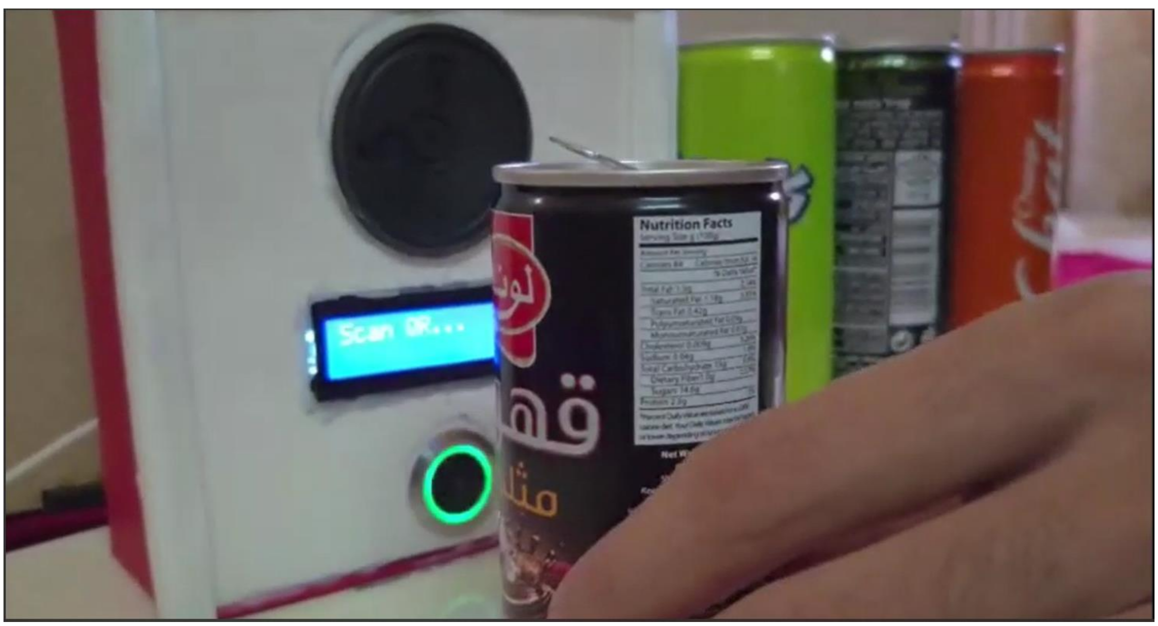

Figure 13: First Product Sample

When scanning the first product (Figure 13), the system identified its status as "Halal and Not Boycotted." The LCD display rendered a positive status indication (Figure 14), while the speaker played an "Allowed" audio message. The buzzer remained inactive, indicating the product met all ethical and religious criteria.

Figure 14: First Product Status Display

c) The Second and Third Product Sample

Figure 15: Second Product Sample

Figure 16: Third Product Sample

The second and third products (Figures 15-16) demonstrated the system's warning capability. When scanned, both triggered the "Not Allowed" audio message and activated the buzzer, indicating ethical or religious restrictions. The LCD displayed corresponding warning statuses (Figures 17-18), clearly communicating the specific restriction (Haram or Boycotted) to the user.

Figure 17: Second Product Status Display

Figure 18: Third Product Status Display

d) Database Management: Adding New Products

We introduced a fourth product sample (Figure 19) to demonstrate the system's flexibility. Using the web interface, we added this product to the database with an initial status of "Haram and Boycotted" (Figure 20). Subsequent scanning triggered appropriate restrictions: the display showed the prohibited status (Figure 21), the speaker announced "Not Allowed," and the buzzer activated.

Figure 19: Fourth Product Sample

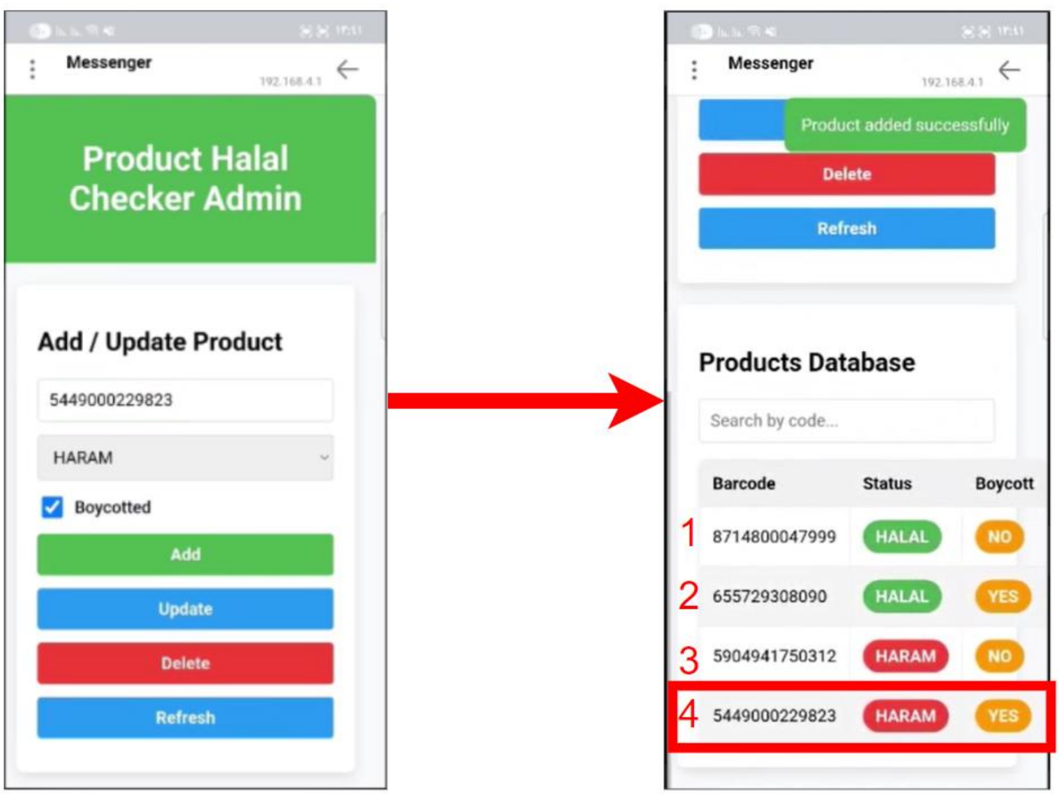

Figure 20: Adding New Product

Figure 21: Fourth Product Status Before Update

e) Database Management : Status Updates

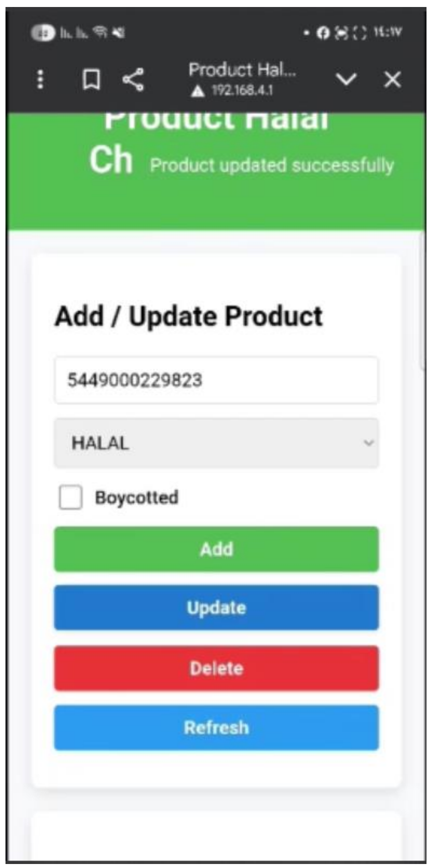

Figure 22: Updating Product Status

The system's adaptability was demonstrated by updating the fourth product's status through the web interface (Figure 22). After changing the classification to "Halal and Not Boycotted," rescanning produced completely different results: a positive "Allowed" audio message, no buzzer activation, and an approved status display (Figure 23).

Figure 23: The Fourth product's Status after Updating

Practical Applications and Benefits

This flexible framework enables personalized customization for various user groups:

- **Parents** can protect children's health by restricting unhealthy snacks (high sugar, artificial ingredients) through custom "Not Allowed" classifications, transforming the scanner into a nutritional guardian.
- **Athletes and Dieters** can maintain strict dietary compliance by restricting foods that contradict their nutritional plans, supporting their health and fitness goals.
- **Allergy Management** While not a medical device, the system provides an additional protective layer by flagging products containing common allergens when properly configured.

This workflow demonstrates that our system transcends conventional scanning technology; it represents a customizable platform for informed decision-making that adapts to religious, ethical, health, and personal preferences. The real-time management capability through a simple web interface ensures the system remains current with evolving consumer needs and information updates.

3.2 Wheelchair

3.2.1 Hardware Components

1- Arduino Mega 2560

The Arduino Mega 2560 serves as the central processing unit of the wheelchair control system. This microcontroller was selected for its extensive input/output capabilities, featuring 54 digital I/O pins and 16 analog inputs, which accommodate the multiple sensors and actuators required for our design. The Mega 2560 performs several critical functions: it continuously reads analog input from the joystick to interpret user movement commands, processes signals from obstacle detection sensors for safety monitoring, and generates precise output signals to control both the drive motors and the linear actuator for seat height adjustment. The board's ATmega2560 processor provides sufficient processing power to handle these real-time control tasks simultaneously while maintaining responsive performance.

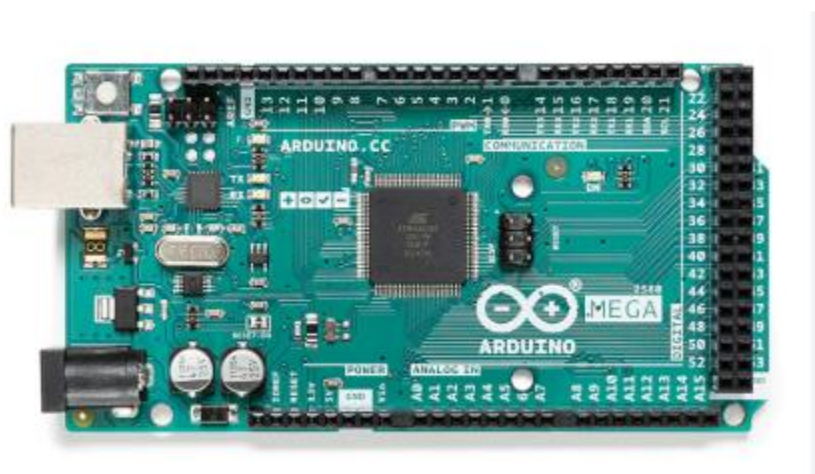

Figure 24: Arduino Mega 2560

2- Joystick Shield for Arduino V1.a

The Joystick Shield integrates directly with the Arduino Mega to provide an intuitive control interface for the user. This shield features a precision analog joystick that enables full-directional movement control - the magnitude and direction of joystick displacement directly correspond to the speed and direction of wheelchair movement. The shield incorporates additional digital input buttons that are programmed for specific functions: two buttons control the chair's rotational movement (±90 degrees) to facilitate access to store shelves, while two additional buttons manage the vertical adjustment of the seat through the linear actuator mechanism. The shield design maintains compatibility with the Arduino's pin layout while providing dedicated analog and digital inputs specifically optimized for mobility control applications.

Figure 25: Joystick Shield for Arduino V1.a

3- 12V DC Linear Actuator (100mm Stroke)

Provides precise vertical adjustment of the seat height, allowing users to reach products placed at different shelf levels. With a 100mm stroke length and 60N force capacity, it offers smooth and stable lifting performance controlled via the L298N driver.

Figure 26: 12V DC Linear Actuator (100mm Stroke)

4- Stepper Motor

Enables precise rotational control of the seat (±90 degrees), facilitating easier access to shelves. Its accurate angular movement ensures users can position themselves optimally without manual effort.

Figure 27: Stepper Motor

5- L298N H-Bridge Driver

Drives both the DC motors for wheelchair movement and the linear actuator for seat adjustment. It interprets low-power control signals from the Arduino Mega to deliver high-power output for motorized functions.

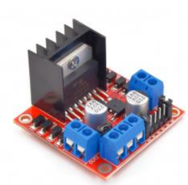

Figure 28: L298N H-Bridge Driver

6- Car Chassis with DC Motors

Forms the structural base of the wheelchair, integrating motors and wheels for movement. Designed for stability and maneuverability, it supports directional control (forward, backward, left, right) as commanded by the joystick.

Figure 29: Car Chassis with DC Motors

7- Ultrasonic Sensor (HC-SR04)

Monitors the environment ahead for obstacles, providing real-time distance measurements to ensure safe navigation. Automatically triggers safety responses if obstacles are detected within a predefined threshold.

Figure 30: Ultrasonic Sensor (HC-SR04)

8- Buzzer

Emits an audible alarm when obstacles are too close, enhancing user safety through immediate auditory feedback.

Figure 31: Buzzer

9- Power Supply System

A dual-battery configuration provides optimized power delivery for different subsystems:

- **Linear Actuator Power**: Four 3.7V lithium batteries connected in series to provide 14.8V nominal voltage, delivering sufficient power for the 12V DC linear actuator's lifting operation.
- **DC Motors Power**: Two 3.7V lithium batteries connected in series to provide 7.4V nominal voltage for the wheelchair's drive motors.
- **Arduino Power**: A separate regulated power supply connected via the Arduino's circular DC input jack, providing stable 7-12V power for the microcontroller and logic circuits, ensuring reliable operation unaffected by motor power fluctuations.

This power configuration ensures each subsystem receives appropriate voltage levels while maintaining safety and stability across all components.

Figure 32: Power Supply (Lithium Batteries)

Figure 33: Power Supply (DC power adapter)

3.2.2 Hardware Implementation

3.2.2.1 System Overview

The wheelchair subsystem has been designed and implemented as an integrated mobility solution that transforms standard wheelchair functionality into an intelligent, responsive assistive device. Built around the Arduino Mega 2560 microcontroller, the system seamlessly combines user control inputs, sensor data processing, and precise motor control to create a safe and adaptable mobility platform.

At the heart of the system, the Arduino Mega serves as the central processing unit, continuously monitoring input from the joystick shield and ultrasonic sensors while coordinating output signals to the motor drivers and actuators. The joystick shield provides intuitive directional control, allowing users to navigate naturally while additional dedicated buttons enable specialized functions including ±90-degree chair rotation and vertical seat adjustment.

The mechanical implementation incorporates a robust car chassis housing DC motors for primary movement, complemented by a stepper motor for precise rotational control and a linear actuator for vertical seat adjustment. Power is efficiently managed through a dual-battery system that separates high-current motor power from sensitive control circuitry, ensuring stable operation throughout various usage scenarios.

Safety features are integrated throughout the design, with ultrasonic sensors continuously monitoring the environment for obstacles and triggering both audible warnings via the buzzer and automatic stopping protocols when necessary. This comprehensive approach to hardware implementation results in a wheelchair system that not only provides basic mobility but actively enhances the user's ability to navigate retail environments and access products independently.

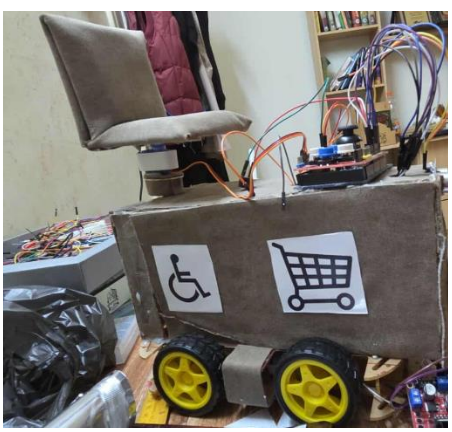

Figure 36: Wheelchair Right View

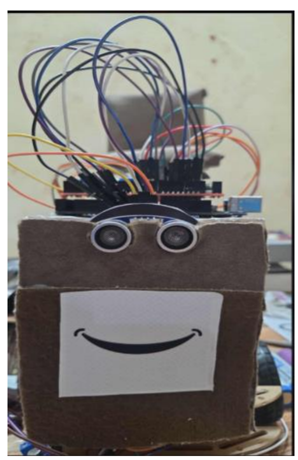

Figure 34: Wheelchair Front View

Figure 35: Wheelchair Left View

3.2.2.2 System Workflow

The wheelchair system operates through an integrated workflow that transforms user commands into precise mechanical actions while maintaining continuous safety monitoring. The operational process is organized around four key functional areas:

1- Wheel Movement Control

Our design philosophy prioritized creating an affordable yet highly functional mobility solution. We implemented a cost-effective approach using a car chassis equipped with four DC motors, each capable of bidirectional movement (forward/reverse). This configuration provides comprehensive directional control through intelligent motor coordination:

- **Forward/Backward Movement**: All wheels rotate synchronously in the same direction (Figures 37-38)
- **Right Movement**: Right wheels rotate forward while left wheels rotate backward, creating a smooth right-turn maneuver (Figure 39)
- **Left Movement**: Left wheels rotate forward while right wheels rotate backward, enabling precise left-turn execution (Figure 40)

This differential steering mechanism allows full omnidirectional movement without requiring complex mechanical components, maintaining both affordability and functional efficiency.

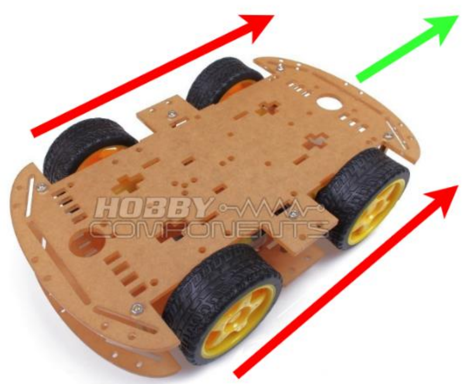

Figure 38: Wheelchair Forward Movement

Figure 37: Wheelchair Backward Movement

Figure 39: Wheelchair Right Movement

Figure 40: Wheelchair Left Movement

2- **Chair Rotation (±90°)**

We implemented precise rotational control using dedicated shield buttons (Button D for right rotation, Button B for left rotation - Figure 44) to enhance user comfort during shopping activities. The system provides:

- **Controlled Rotation**: Stepper motor enables exact ±90-degree rotations (Figures 41-43)
- **Ergonomic Design**: Eliminates need for upper body twisting, reducing physical strain.
- **Shelf Accessibility**: Positions users directly facing store shelves for optimal reach
- **Middle Position Maintenance**: Automatic stopping at neutral position (Figure 42) ensures stability.

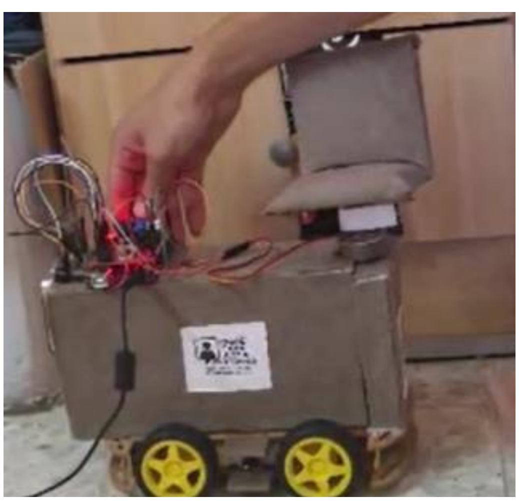

Figure 41: Left Rotation

Figure 42: Middle State

Figure 43: Right Rotation

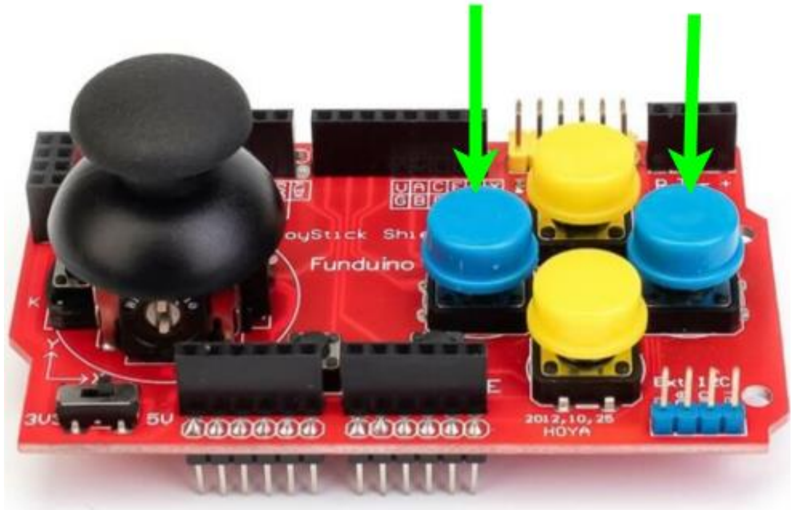

Figure 44: Chair Rotation Control Buttons

3- Vertical Chair Movement

The vertical movement mechanism addresses accessibility challenges through linear actuator technology controlled via shield buttons (Button A for upward movement, Button C for downward movement - Figure 47). This system provides:

- **Extended Reach**: 100mm vertical stroke enables access to both high and low shelves (Figures 45-46)
- **Safety Engineering**: Eliminates need for potentially dangerous reaching tools
- **Weight Capacity**: 60N force capability supports practical shopping scenarios (e.g., handling heavy items like honey jars)
- **Controlled Speed**: 8mm/s movement rate ensures stability and precision during adjustment

Figure 46: Moving Chair Downward

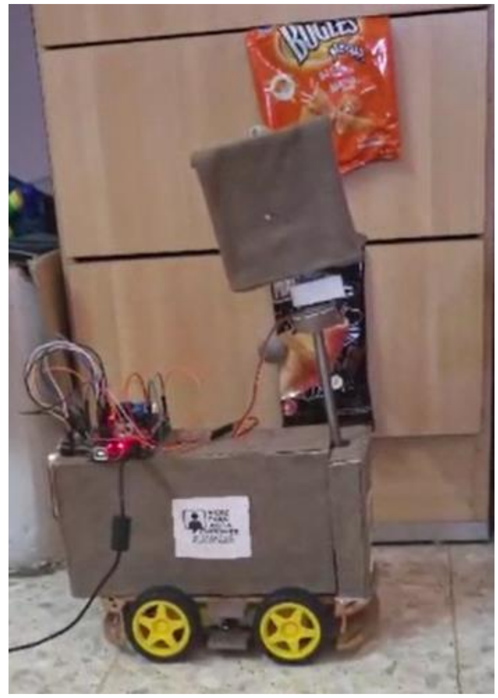

Figure 45: Moving Chair Upward

Figure 47: Vertical Movement Control Buttons

4- Obstacle Detection

We integrated a comprehensive safety system using ultrasonic sensors with proactive threat detection:

- **Continuous Monitoring**: HC-SR04 sensors provide real-time distance measurement
- **Intelligent Response**: Automatic braking triggered at 10cm obstacle proximity
- **Auditory Alert**: Buzzer activation provides immediate user warning (Figure 48)
- **Fail-Safe Operation**: System prioritizes safety over movement commands when obstacles detected

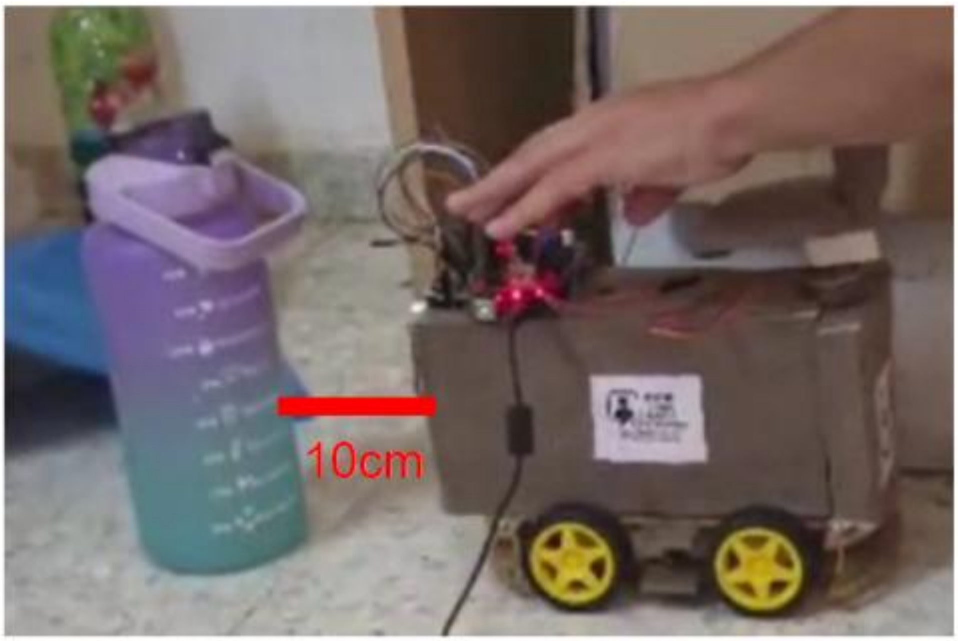

Figure 48: Obstacle Detection

This optimized workflow represents a balance between technical sophistication and practical usability, providing users with independent mobility while maintaining multiple layers of safety protection. The system's design successfully achieves our goal of creating an affordable yet highly functional assistive device that enhances both mobility and accessibility in retail environments.

Chapter 4

Results and Discussion

This chapter presents a detailed analysis of the key challenges encountered during the implementation of the wheelchair subsystem and the adaptive solutions developed to address them. Each major problem is discussed in a dedicated subsection, highlighting the practical constraints, design decisions, and performance outcomes that shaped the final prototype.

4.1 Scale and Resource Constraints

Problem:

The initial goal was to build a full-scale, functional wheelchair. However, due to the high cost of specialized components (e.g., wheelchair frames, high-torque motors) and their limited availability in local markets, this approach proved infeasible.

Solution:

We pivoted to a scaled-down prototype that retained all core functionalities using more accessible and affordable components:

- Replaced a commercial wheelchair frame with a modified car chassis.
- Used standard DC motors instead of custom wheelchair motors.
- Sourced generic electronic parts (sensors, controllers) to reduce cost.

Discussion:

While the scaled prototype does not match the form factor of a commercial wheelchair, it successfully demonstrates:

- All targeted mobility features (directional control, rotation, vertical lift).
- Integration of safety and control systems.
- Cost-effectiveness and reproducibility.

This approach allowed validation of the technical concept and provided a foundation for future scaling.

4.2 Power Management and Drive System Optimization

Problem:

The initial four-wheel drive system (with two H-bridges) consumed excessive power, leading to short battery life and complex wiring.

Solution:

We redesigned the drive mechanism to use only two motors in a diagonal configuration:

- Used the left front and right rear wheels for traction.
- Implemented differential steering for turning (e.g., right turn: left motor forward, right motor backward).
- Retained a single H-bridge for motor control.

Discussion:

The new configuration resulted in:

- A reduction in power consumption.
- Simplified control logic and reduced wiring complexity.
- No loss of functionality—full directional control was maintained.
- Longer operation time between charges.

This optimization highlights how resource constraints can drive innovative and efficient design choices.

4.3 Control Interface Reliability

Problem:

Two of the four control buttons (left rotation and down movement) became unstable due to mechanical wear and electrical noise, reducing usability.

Solution:

We replaced the multi-button interface with a state-machine-based toggle system:

- Vertical movement: One button toggles between UP and DOWN states.
- Rotation: One button cycles through LEFT, MIDDLE, and RIGHT states.
- Software-based debouncing ensured reliable triggering.

Discussion:

The state-machine approach:

- Eliminated reliance on faulty hardware.
- Reduced the number of physical components.
- Improved user experience with intuitive state transitions.
- Ensured full functionality with greater reliability.

This solution demonstrates how software can compensate for hardware limitations.

4.4 Mechanical Integration and Component Placement

Problem:

Mounting the control panel on the moving part of the chair caused wire fatigue, restricted movement, and created weight imbalance.

Solution:

We reorganized the layout as follows:

- Mounted the Arduino, the joystick shield control panel and primary electronics on the fixed chassis.
- Used flexible, strain-relieved cables to connect moving parts.
- Centralized power distribution near the base.

Discussion:

The new layout:

- Prevented wire damage during chair movement or rotation.
- Allowed full vertical and rotational range without interference.
- Simplified maintenance and component access.

This adjustment underscores the importance of holistic mechanical design in mechatronic systems.

4.5 Conclusion

The challenges faced during this project—ranging from resource limitations to component reliability—were addressed through iterative design and adaptive engineering. Each solution not only resolved the immediate issue but also contributed to a more efficient, reliable, and user-friendly system. The resulting prototype validates the core concept of an intelligent, multi-functional wheelchair and provides a strong foundation for future development toward a full-scale product. These experiences highlight the value of flexibility and innovation in engineering design, especially when working under constraints.

Chapter 5

Future Work

1. Enhanced Wheelchair Frame Design

A full-sized, ergonomic wheelchair frame would improve real-world usability. This would include reinforced construction for durability, improved weight distribution for stability, and adjustable components to accommodate different user needs. These enhancements would ensure greater comfort and safety during daily use.

2. Mobile Application Integration

A dedicated mobile app would expand system capabilities and accessibility. It would enable remote control of wheelchair functions, provide real-time product information, and offer voice-guided store navigation. The app would also support cloud-based updates and personalized user profiles for a more integrated experience.

3. AI-Powered Recommendation System

Implementing artificial intelligence would significantly enhance the system's intelligence. An AI module could suggest alternative products for restricted items, learn user preferences over time, and provide personalized nutritional information. Integration with store inventory systems would help users locate suitable products quickly.

4. Advanced Power Management System

Optimizing the power system would support extended daily use. This would involve high-capacity batteries with fast-charging capability, possibly supplemented with solar charging technology. A smart power management system would monitor energy usage and provide reliable battery status information to users.

Conclusion

The "More Than Just a Customer" project successfully demonstrates an innovative and practical approach to enhancing independence and safety for people with disabilities during shopping experiences. By integrating a smart scanner with a functionally adaptive wheelchair, the system addresses both physical accessibility and informed decision-making in retail environments.

Through the development of this prototype, we have shown how readily available components can be combined to create a meaningful assistive technology solution. The wheelchair subsystem provides intuitive mobility with features like rotational movement and vertical adjustment, while the smart scanner delivers real-time product information through multi-modal feedback. Despite facing challenges related to scalability, power management, and component reliability, the team developed effective solutions such as the state-based control system and optimized drive configuration that not only resolved these issues but improved overall system performance.

This project underscores the importance of user-centered design in assistive technologies. By focusing on real-world needs—such as the ability to reach items on shelves, navigate store aisles safely, and make choices aligned with personal values—the system moves beyond theoretical concepts to offer tangible benefits. The working prototype validates the core concept and provides a strong foundation for future development toward a commercially viable product.

Ultimately, this project contributes to the broader goal of creating more inclusive environments where technology empowers individuals with disabilities to participate fully in everyday activities with confidence and independence.

References

[1] P. Viswanathan, J. Boger and J. Hoey, "The Development of a Smart Wheelchair for Older Adults with Cognitive Impairment," in Technology and Innovation, vol. 18, no. 2-3, pp. 83-95, 2016. doi: 10.21300/18.2-3.2016.83.

[2] Z. Rashid, J. Melià-Segui, R. Pous and E. Peig, "Using RFID to Detect Interactions in Ambient Assisted Living Environments," in IEEE Intelligent Systems, vol. 32, no. 4, pp. 16-22, July-Aug. 2017. doi: 10.1109/MIS.2017.3121556.

[3] R. C. Simpson, "Smart Wheelchairs: A Literature Review," in Journal of Rehabilitation Research and Development, vol. 42, no. 4, pp. 423-36, July 2005. doi: 10.1682/JRRD.2004.08.0101.

[4] D. Dakopoulos and N. G. Bourbakis, "Wearable Obstacle Avoidance Electronic Travel Aids for Blind: A Survey," in IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), vol. 40, no. 1, pp. 25-35, Jan. 2010. doi: 10.1109/TSMCC.2009.2021255.

[5] A. K. Das et al., "A Low-Cost Smart Wheelchair Framework for Developing Countries," in *2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*, Dhaka, Bangladesh, 2017, pp. 766-769, doi: 10.1109/R10-HTC.2017.8289066.

Link: https://ieeexplore.ieee.org/document/8318978

[6] P. K. Sankaran, "Voice and Gesture Controlled Smart Wheelchair," in 2017 International Conference on Inventive Computing and Informatics (ICICI), Coimbatore, India, 2017, pp. 945-949, doi: 10.1109/ICICI.2017.8365279.

Link: https://ieeexplore.ieee.org/document/8340734

[7] S. S. Kulkarni and A. A. Shinde, "Vision Based Smart Cart for Blind People," in 2021 6th International Conference for Convergence in Technology (I2CT), Maharashtra, India, 2021, pp. 1-5, doi: 10.1109/I2CT51068.2021.9418157.

Link: https://ieeexplore.ieee.org/document/9701077

[8] M. A. Al-Shaqi, M. H. A. Al-Khalifa and A. S. Al-Salman, "An Assistive Shopping System for the Visually Impaired," in 2015 International Conference on Cloud Computing (ICCC), Riyadh, Saudi Arabia, 2015, pp. 1-5, doi: 10.1109/CLOUDCOMP.2015.7149634.

Link: https://ieeexplore.ieee.org/document/7412931