Smart Kart: Development Proposal

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1. Product Description

The Smart Kart is an innovative shopping cart attachment designed to improve accessibility and ease of shopping. By integrating barcode scanners, RFID readers, weight sensors, and AI-driven product recognition, the Smart Kart enables hands-free scanning and verification of products. The system provides real-time feedback through audio, visual, and haptic outputs to assist users, particularly those with visual impairments or dexterity challenges.

How It Works

1. As the shopper places an item in the cart, the barcode scanner or RFID reader scans the product.
2. The weight sensor verifies the presence of the item and prevents unscanned items from being placed.
3. The camera module provides additional verification and can recognize unlabeled items using AI.
4. The system provides feedback through a speaker (audible confirmation), buzzer alarm (alerts for errors), and visual display (text-based confirmation).
5. The Smart Kart connects to a mobile app via Wi-Fi, where users can track their purchases and receive notifications.

Key Feature: Assisting with verifying ingredients (on labels) of selected groceries.

2. Requirements

2.1 Functional Requirements

1. Automatic Item Detection
    - The system must detect items via barcode scanner and optionally RFID.
    - The weight sensor validates that the scanned product matches the expected weight (e.g., to prevent scanning errors).
2. Audio Feedback
    - When an item is successfully scanned, the system provides an audio confirmation announcing the product name and any relevant ingredient or allergy information.
3. Item Verification
    - If an item is placed in the cart without being properly scanned, a buzzer or audio alert notifies the user.
4. User Interface via Buttons
    - Tactile buttons (Triangle, Square, X, Circle) allow the user to repeat audio information, skip, or confirm next steps (e.g., next item, instructions).
5. Connectivity
    - The Raspberry Pi communicates via Wi-Fi to a central store system or a companion mobile app to log purchased items.

2.2 Non-Functional Requirements

1. Ease of Use
    - Must be intuitive for shoppers with visual impairments or limited dexterity.
2. Portability & Durability
    - The sensor suite and enclosure must withstand regular use in shopping environments and be attachable/detachable from carts easily.
3. Performance
    - The scanning process should complete within 1–2 seconds, providing near-instant feedback.
4. Security & Privacy
    - Customer data (e.g., shopping lists) should remain secure; minimal personal data storage on the device.
5. Cost-Effectiveness
    - Aim to minimize hardware and manufacturing costs to facilitate large-scale adoption.

2.3 Constraints

1. Power Constraint
    - System relies on a power bank (10,000mAh or more). Must manage power usage efficiently.

2. Size & Weight Constraint
    - Components must not overly increase the cart’s weight or occupy too much space.
3. Integration with Existing Carts
    - The mounting hardware must adapt to most standard shopping cart designs.

3. Detailed Sensors and Outputs Table

Below is a breakdown of each input and output component, along with its purpose in the Smart Kart system

Component	Type	Purpose	Example / Link
Barcode Scanner (Zebra SE4710)	**Input Sensor**	Reads product barcodes for item identification.	Zebra SE4710 on Amazon
RFID Module (RC522) (Optional)	**Input Sensor**	Reads RFID/NFC tags for item identification (advanced use case).	RC522 RFID on Amazon
Load Cell + HX711 Amplifier	**Input Sensor**	Measures the weight of items placed in the cart.	HX711 Load Cell Kit
Camera Module (Raspberry Pi Cam)	**Input Sensor**	For image-based recognition of items without barcodes.	Raspberry Pi Camera V2
4 Tactile Buttons	**User Input**	Allows user interactions such as repeat info, next item, etc.	GPIO Buttons
Speaker (USB or 3.5 mm)	**Output**	Provides audible feedback of item details and alerts.	USB Speaker
Buzzer / Alarm	**Output**	Alerts user to items not scanned or errors.	Active Buzzer
Microphone (Optional)	**Input**	Allows voice commands for advanced functionality.	USB Microphone
Wi-Fi (Built-In on RPi 4)	**Connectivity**	Syncs data with store POS or cloud-based database.	*(Built-in on Raspberry Pi 4)*

4. Bill of Materials (BOM)

Item	Description & Purpose	Example Link	Estimated Cost (USD)
Raspberry Pi 4 (4GB or 8GB RAM)	Main processing unit for running system software, sensor inputs, and providing audio/visual feedback.	Amazon Link	\$55–\$85
32GB MicroSD Card	Stores the Raspberry Pi OS, software libraries, and local databases.	Amazon Link	\$12–\$18
Portable Power Bank (10,000mAh or higher)	Powers the Raspberry Pi and peripherals, ensuring the cart remains mobile without needing a constant wall connection.	Amazon Link	\$25–\$45
Barcode Scanner Module (e.g., Zebra SE4710)	Reads barcodes for item identification. High-end modules like Zebra have better accuracy and durability, but generic USB scanners are available.	Amazon Link	\$70–\$125
RFID Reader Module (RC522, Optional)	Enables RFID/NFC scanning for advanced item or user identification.	Amazon Link	\$8–\$15
Load Cell + HX711 Amplifier	Measures the weight of items placed in the cart; essential for cross-verifying scanned items.	Amazon Link	\$8–\$25
Raspberry Pi Camera (V2 or HQ)	Provides optical item recognition for products without scannable barcodes.	Amazon Link	\$25–\$75
Speaker (USB or 3.5mm)	Outputs voice confirmations and alerts (e.g., product name, nutritional info, error messages).	Amazon Link	\$12–\$25
Tactile Buttons & Wiring	Physical interface for user inputs (e.g., repeat info, next item). Connect to Raspberry Pi GPIO pins.	Amazon Link	\$8–\$15
Custom 3D-Printed Enclosure	Protects the hardware (Pi, power bank, scanners) and provides a mountable, user-friendly form factor on shopping carts.	Local/Online 3D Print Service	\$12–\$35

Total Cost Analysis

Based on the detailed component pricing above, the total estimated cost for this Raspberry Pi shopping cart system ranges from $235-$420, with variability depending on component quality choices and whether optional components are included.

A basic implementation using the lower-cost options and excluding the RFID reader would cost approximately $235, while a premium implementation with higher-quality components and all optional elements would approach $420.

Cost Breakdown

- Basic Build: (No RFID, standard-quality components)
  Approx. $235 total
- Advanced Build: (Includes RFID module, higher-end scanner, camera, larger power bank)
  Approx. $420 total

5. Software Components

The software stack consists of several key elements.

Operating System

- Raspberry Pi OS (Raspbian)
  - The main OS for running Python scripts.

Programming Languages

- Python 3.x – Main language for scripting.

Libraries & Dependencies

- OpenCV – Handles computer vision (for image-based item recognition).
- PyTesseract – OCR (Optical Character Recognition) for reading text labels.
- PyZbar – Barcode scanning.
- Google Text-to-Speech (gTTS) – Converts item details into speech.
- SpeechRecognition – Allows voice commands.
- SQLite – Local database storage for item tracking.
- HX711 Python Library – Reads weight sensor data.

GPIO Zero – Manages button inputs.

6. Product Sketch

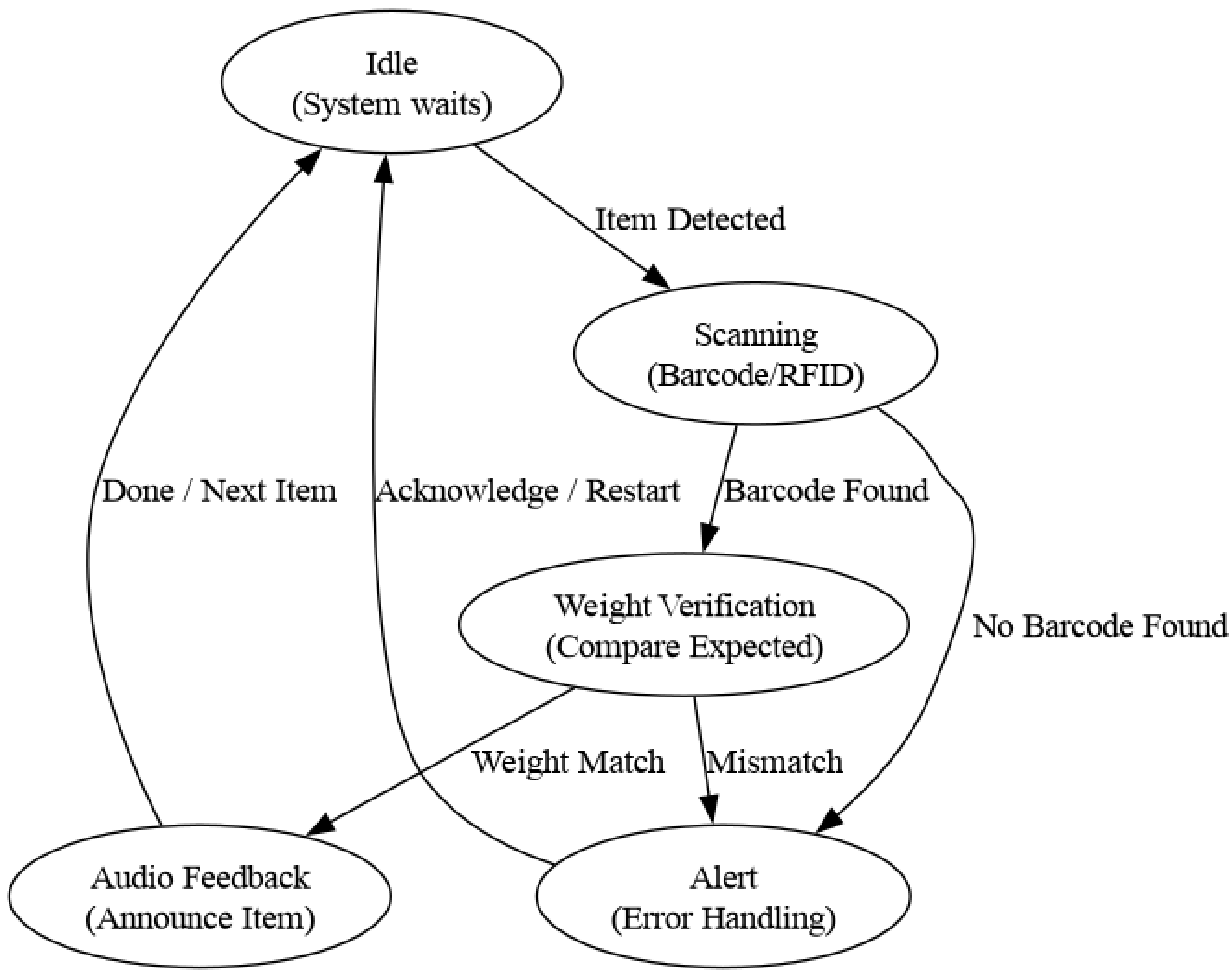
Key Points:

- Camera, Barcode Scanner, RFID Module are positioned near the top to easily read item labels as they are placed in the cart.
- Weight Sensor is installed on the cart base where items rest.
- Buttons & Speaker are easily accessible on the handle for user interaction and feedback. 4 physical protruding buttons on the face with tactile feeling (unique shapes: circle, square, cross, triangle, or etc)

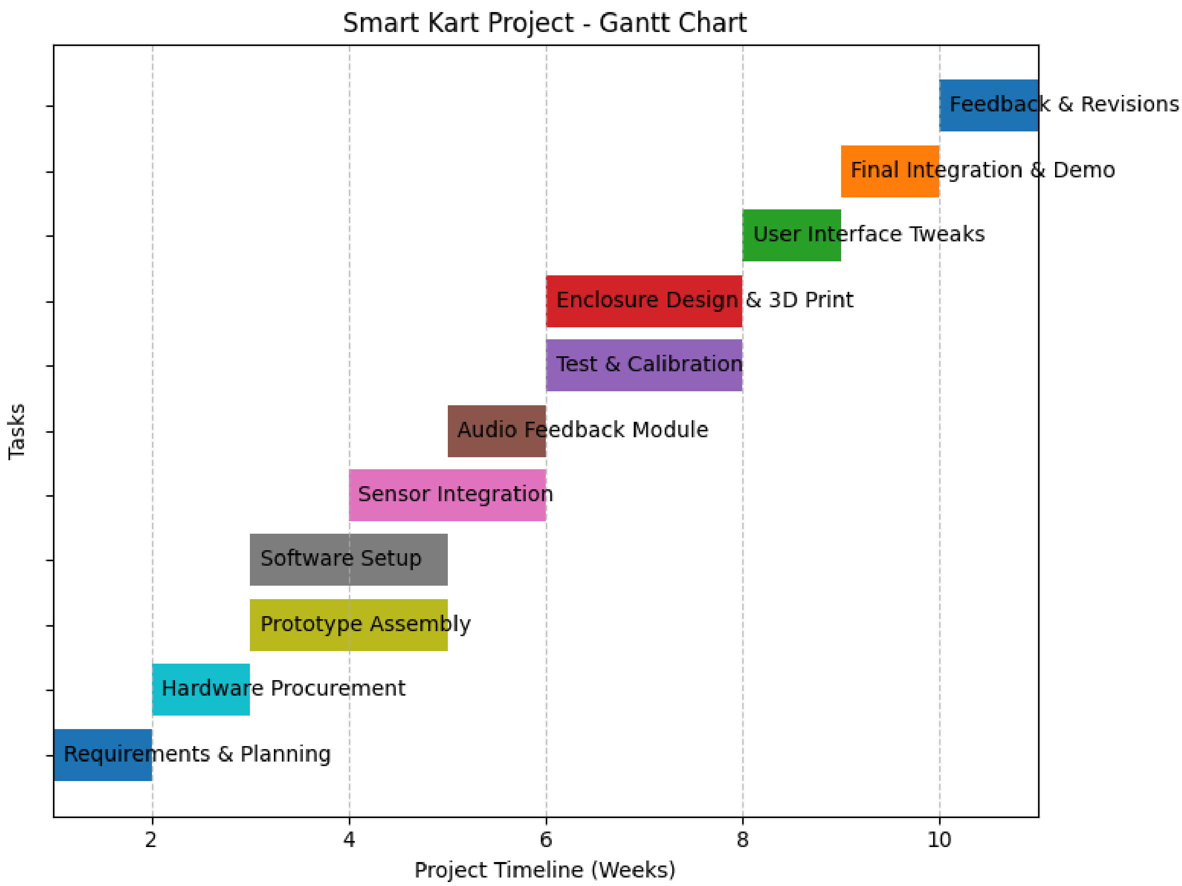
7. State Diagram

Flow Explanation:

1. Idle: System waits until it detects an item (via weight change or motion sensor).
2. Scanning: Barcode/RFID is scanned.
3. Weight Verification: Confirms item weight matches product data.
4. Audio Feedback: Announces item name/ingredients if everything is valid.
5. Error Handling: If the item is not scanned properly or weight mismatch occurs, system alerts the user.



8. Gantt Chart



8. Feedback and Approval

Instructor/TA Feedback Summary

- Ensure the weight sensor calibration is robust enough for different packaging sizes.
- Consider adding a haptic feedback mechanism for environments with high noise levels.
- Clarify how the user interface handles voice commands if a microphone is included.

Response to Feedback

1. Weight Sensor Calibration
    - We will implement an auto-calibration routine on system startup to fine-tune the weight sensor.
2. Haptic Feedback
    - We plan to add a small vibration motor as an optional module.
3. Voice Command Interface

Integration with the SpeechRecognition library is underway, contingent upon hardware testing results.

9. Conclusion

The Smart Kart project addresses the core pain points identified: difficulty reading labels and the challenges of traditional scanning solutions. With a combination of barcode/RFID scanning, weight verification, audio feedback, and optional voice/haptic interfaces, our solution aims to deliver an inclusive, user-friendly shopping experience for all.

Next Steps:

1. Finalize hardware mounting.
2. Implement calibration scripts for sensors.
3. Perform user testing to refine the UI/UX.

Upon completion of these steps, the Smart Kart will be ready for a pilot deployment in a real-world store environment.