Project Milestone#2: Smart Shopping Cart System Architecture

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1. System Overview The smart shopping cart integrates QR/barcode scanning, an ML-based recommendation system, and real-time billing updates. It is powered by a Raspberry Pi or ESP32, with a battery as the primary power source and Wi-Fi for communication.

2. Key Components

- **Raspberry Pi/ESP32**: Main processing unit handling barcode scanning, ML model, and UI.
- **QR/Barcode Scanner**: Captures product information for automatic billing.
- **Battery Pack**: Powers the system.
- **Wi-Fi Module**: Connects the cart to the shopping mall's network.
- **Display (Optional)**: Shows product details, recommendations, and billing updates.

3. Data Flow

1. Customer scans item QR/barcode using the scanner.
2. Data is sent to the Raspberry Pi/ESP32 for processing.
3. The scanned product details are fetched from a local database.
4. The ML model analyzes the cart contents and suggests additional products.
5. Updated cart details and recommendations are displayed on the screen.
6. The billing system updates in real time.

4. Diagram Structure

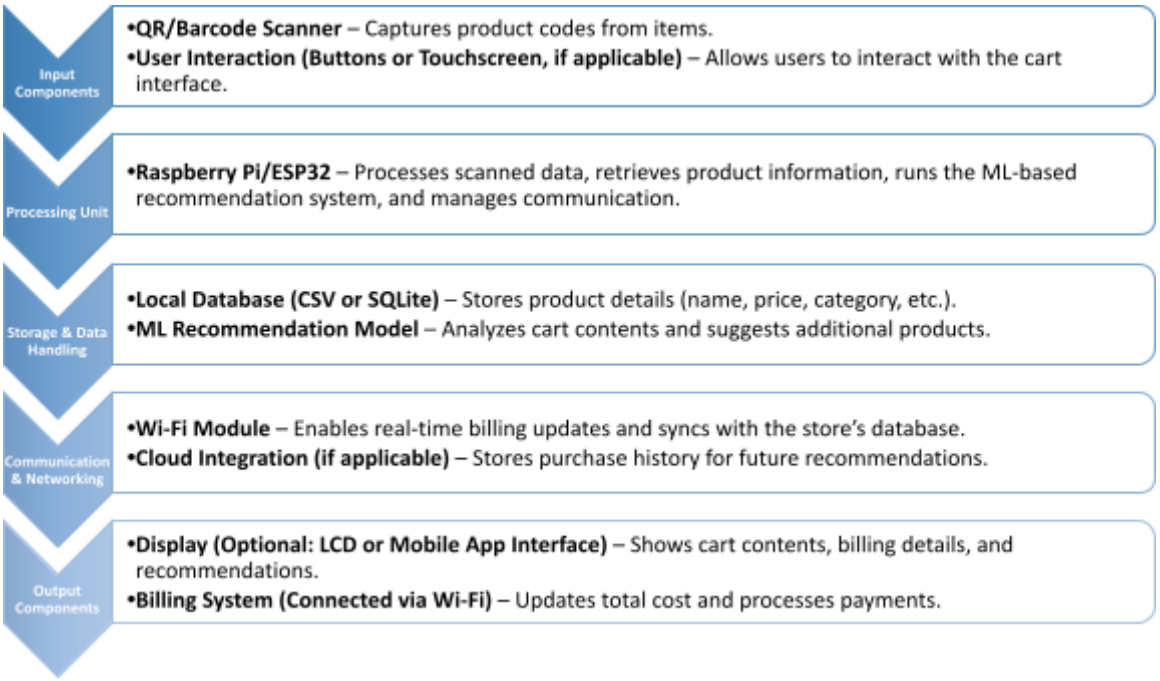
- Use PowerPoint to create a block diagram.
- Represent key components as blocks (e.g., Raspberry Pi, Scanner, Display, etc.).
- Use arrows to show data flow (e.g., scanning -> processing -> display -> billing system).
- Label connections (e.g., Wi-Fi, power source, data processing).

5. Next Steps

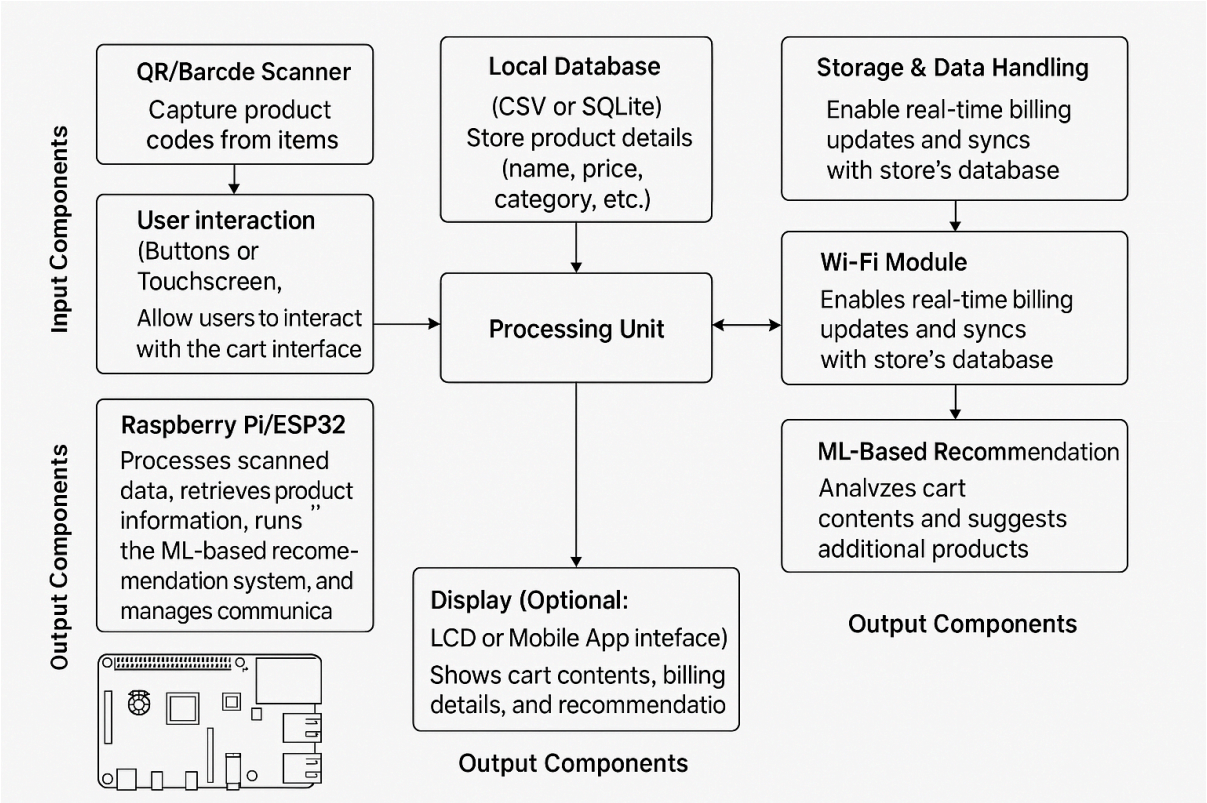
- Refine the diagram based on hardware selection.
- Ensure all data flow interactions are clearly represented.
- Integrate this into the final presentation and documentation.

System Architecture Diagram

Block Diagram



system architecture:



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Hardware Component Selection

- **Raspberry Pi 4 Model B**
    - **Specifications:** Quad-core Cortex-A72, 2GB/4GB RAM, Wi-Fi, Bluetooth, USB, HDMI.
    - **Justification:** Capable of handling QR scanning, ML processing, and UI display.
    - **Alternative:** ESP32 (Lower processing power but more energy-efficient).
    - **URL:** Core Electronics
- **QR/Barcode Scanner Module**
    - **Specifications:** CMOS sensor, USB/UART interface, 3.3V-5V power supply.
    - **Justification:** Enables automatic item addition.
    - **Alternative:** Mobile phone scanning (Not standalone, needs additional app development).
    - **URL:** Core Electronics
- **Touchscreen Display (Optional: 7-inch LCD)**
    - **Specifications:** 1024x600 resolution, HDMI interface.
    - **Justification:** Provides real-time cart details and recommendations.
    - **Alternative:** OLED display (Limited screen space).
    - **URL:** Core Electronics
- **Battery Pack (Lithium-ion, 10,000mAh)**
    - **Specifications:** 5V output, rechargeable.
    - **Justification:** Enables portability.
    - **Alternative:** Power bank (Bulkier, but removable).
    - **URL:** Core Electronics
- **Wi-Fi Module (Built-in on Raspberry Pi 4)**
    - **Specifications:** 2.4GHz/5GHz dual-band Wi-Fi.

- **Justification:** Enables real-time billing updates.
- **Alternative:** External Wi-Fi dongle (Unnecessary for Raspberry Pi 4).

Hardware Component Selection

- **Estimated Power Consumption of Major Components:**
  - **Raspberry Pi 4 Model B**: ~3W to 6W (depends on processing load)
  - **QR/Barcode Scanner**: ~1.5W
  - **7-inch LCD Display (if used)**: ~4W
  - **Wi-Fi Module (Integrated in Raspberry Pi 4)**: ~1W
  - **Total Estimated Power Consumption:** ~10W-12W (without deep sleep modes)
- **Choice of Power Source:**
  - **Battery Pack (Lithium-ion, 10,000mAh, 5V output)**
  - Justification: Provides sufficient power for continuous operation for several hours before requiring a recharge.
  - Alternative: USB Power (Limited to tethered use), Solar Power (Not practical for indoor shopping environments).
- **Power Efficiency Strategies:**
  - **Low-Power Mode:** Reduce Raspberry Pi processing load when idle.
  - **Deep Sleep Mode (ESP32 Alternative):** ESP32 enters sleep mode when not in use to conserve battery.
  - **Dynamic Display Control:** Turn off the display when the cart is idle for a period.
  - **Wi-Fi Optimization:** Reduce background data sync frequency to conserve energy.

Communication and Data Flow

- **Communication Between Components:**
  - **QR/Barcode Scanner to Raspberry Pi/ESP32:** Data is transmitted via USB/UART.
  - **Raspberry Pi/ESP32 to Local Database:** Processes scanned data and updates cart details.
  - **ML Recommendation Model Processing:** Runs locally to generate personalized product suggestions.
  - **Wi-Fi Module to Store Server:** Transmits cart updates and billing data in real time.

- **Display Module (if used):** Shows cart contents, recommendations, and total bill.

- **Data Processing and Transmission:**
  1. **Item Scanning:** The barcode scanner captures product data and sends it to the Raspberry Pi/ESP32.
  2. **Data Lookup:** The Raspberry Pi/ESP32 fetches product details from the local database.
  3. **ML-Based Recommendation:** The system analyzes cart contents and generates recommendations.
  4. **User Interaction:** The display or app interface presents cart details and recommendations.
  5. **Billing and Cloud Sync:** The final bill is sent to the store's system via Wi-Fi for payment processing.
- **Data Logging and Retrieval:**
  - **Local Storage:** Stores scanned product data for real-time updates.
  - **Cloud Integration (if applicable):** Logs purchase history for future recommendations.
  - **User Interaction Data:** Records customer preferences for ML training and refinement.

System Integration Challenges and Solutions

Challenges:

- **Hardware Compatibility Issues:** Ensuring all components use compatible communication protocols (USB, UART, I2C, etc.).
- **Power Limitations:** Managing power consumption effectively to extend battery life.
- **Latency in Data Processing:** Ensuring real-time updates for product scanning and billing.
- **Wi-Fi Connectivity:** Handling unstable connections in shopping environments.
- **Scanning Accuracy:** Ensuring accurate barcode/QR code scanning with different product surfaces.
- **Security and Privacy:** Protecting user data and transaction details.

Solutions:

- **Hardware Compatibility:** Select components with standardized interfaces and perform integration testing.
- **Power Optimization:** Utilize sleep modes and efficient power management techniques.
- **Latency Reduction:** Optimize data processing algorithms and use local caching for frequently accessed information.

- **Wi-Fi Reliability:** Implement offline mode with synchronization when the connection is restored.
- **Improved Scanning:** Use high-quality scanners with built-in error correction and a manual input fallback option.
- **Data Security:** Encrypt all data transmissions and anonymize user data to ensure privacy.