Automated Smart Shopping Cart

Software Systems Architecture

Group 7 – Class 3

Master in Informatics and Computing Engineering

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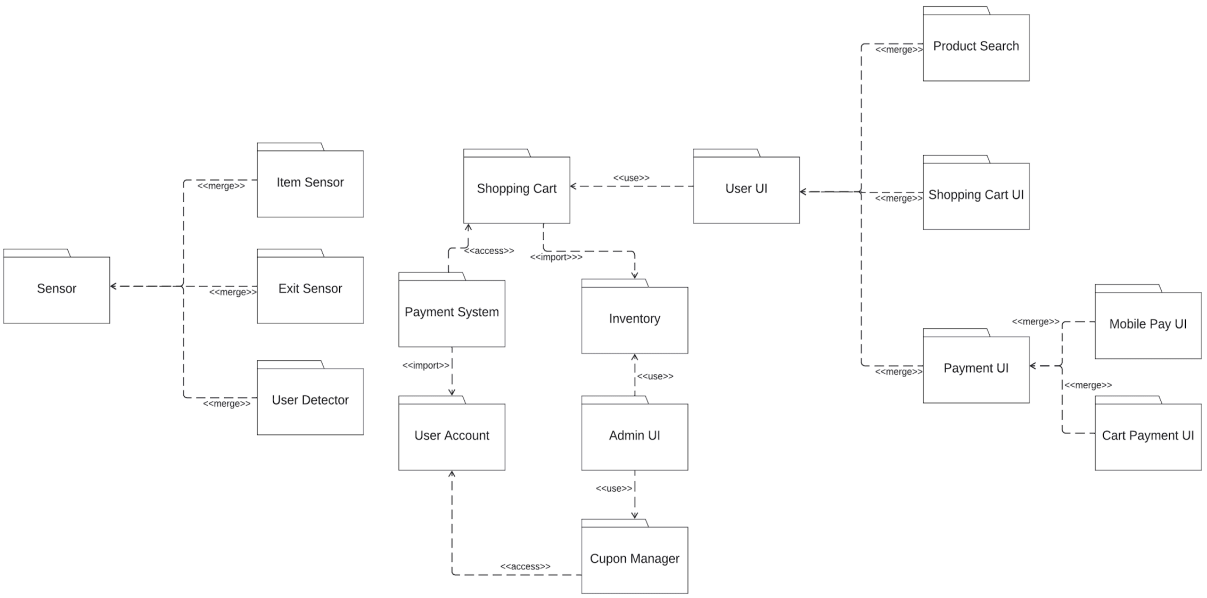
1. Introduction

In this report, we present the architecture for **an Automated Smart Shopping Cart system**. This innovative solution aims to bridge the convenience gap between online and physical shopping by offering real-time item detection, running total display, and streamlined checkout processes.

Leveraging a combination of hardware sensors, mobile applications, and server-side components, our **architecture ensures availability, usability, reliability, and security while enhancing the overall shopping experience for customers**.

Through this report, we detail the **structural design, key use cases, and quality attributes handled by the system architecture**.

2. Structure diagrams



Sensors:

- The Item, Exit, and User sensors are all responsible for the observation and creation of events in the stores. Namely:
    - The **item sensor** is responsible for checking if the user has grabbed or put back an item in the store. These events will ultimately modify the shopping cart of that user.
    - The **exit sensor** is responsible for starting the checkout process, described in detail in the use cases section. When a user exits the store, a billing process should take place. If the user fails to pay then an alarm goes off.
    - The **user detector sensor** is responsible for the association between a shopping cart and a user. It must correctly identify the user that is

holding the shopping cart and correctly identify the exchange of shopping cart ownership, which impacts the coupons applied.

Shopping cart:

- The shopping cart associates items from the inventory with users holding those items. One can add or remove items from the shopping cart. As mentioned, sensors are responsible for the execution of those operations.

Payment System:

- The payment system initiates the payment process by utilizing both the user's shopping cart and their payment information. Once initiated, this process triggers a notification to the user, awaiting their approval in the payment UI. This system is responsible for guaranteeing the correctness of the transactions. It can utilize either the user's specified preferred payment method or the physical payment method available in the shopping carts.

Admin UI & Coupon Manager:

- The Admin UI is specially designed for employees of the store. With it, it is easier to manage inventories and other key operations like for instance discounts. Sometimes managers want to apply marketing campaigns directed at a particular customer segment. We made the following distinction between coupons and discounts:
    - **Discounts** are applied directly to the product and there is no need for affiliation with the company for the discount to take place. A manager could simply lower the price of a product to apply a discount to it.
    - **Coupons** on the other hand are given directly to affiliated customers. In an attempt to maintain customer loyalty and retention. For that to work we depict a **Cupon manager** package that allows for the store manager to reach the right customers. For example, imagine that the manager is trying to captivate customers with children, the coupon manager would filter the customers and select those that match the criteria.

User UI:

- The **User UI** is responsible for the presentation of key data to the users, namely:
    - A **product search UI** for app users (either authenticated or not) to see available products.
    - A **shopping cart UI** that displays the items added to the physical shopping cart along with their respective prices. Additionally, it shows the total amount to be paid both with and without the application of coupons.
    - A **payment interface UI** is available in both mobile and "on-the-cart" versions. These interfaces appear after receiving a notification from the payment system to confirm the payment.

3. Message sequence diagrams

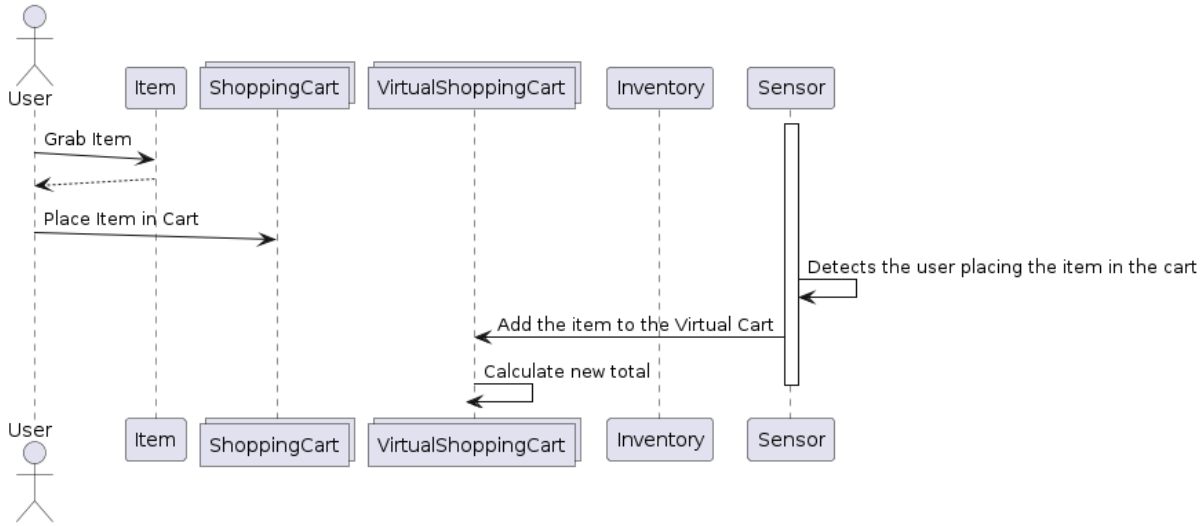
In this chapter we will go over the sequence diagrams for two key use cases: Adding an item to the cart and doing the checkout for the purchase. This will help us understand how parts of the system communicate with each other, and the order of actions.

3.1 Adding an item to the cart

For this process is important to distinguish between two entities: a **Shopping Cart (the real and physical cart, with all the items inside)** and a **Virtual Shopping Cart (the virtual list of items the sensors detected the user from adding to its cart)**.

For an Automated Smart Shopping cart, **adding an item to a cart**, **for the user**, is business as usual: **simply grab the item and place it in the cart**.

When a **sensor detects that a user added an item to his Shopping Cart,** it **adds the item to the Virtual Shopping Cart**, and it r**ecalculates the new price total according to the item's value**.



3.2 Walking out of the store (checkout)

Now we will take a look at the checkout.

The **checkout starts when a user enters the checkout area, and it is detected by a sensor**.
It is important to notice that, at any point, if the User tries to exit the store without the confirmation of the payment, the alarm of the store goes off.

The **Checkout UI** (can be either on the phone, if the user has the app, or on the shopping cart), **shows all the information about the cart (items, cost, etc…) and handles interactions with the user**. As both the app and the device in the cart have a similar UI no

distinction was made in the process diagram to simplify and understand more clearly the actual actions.

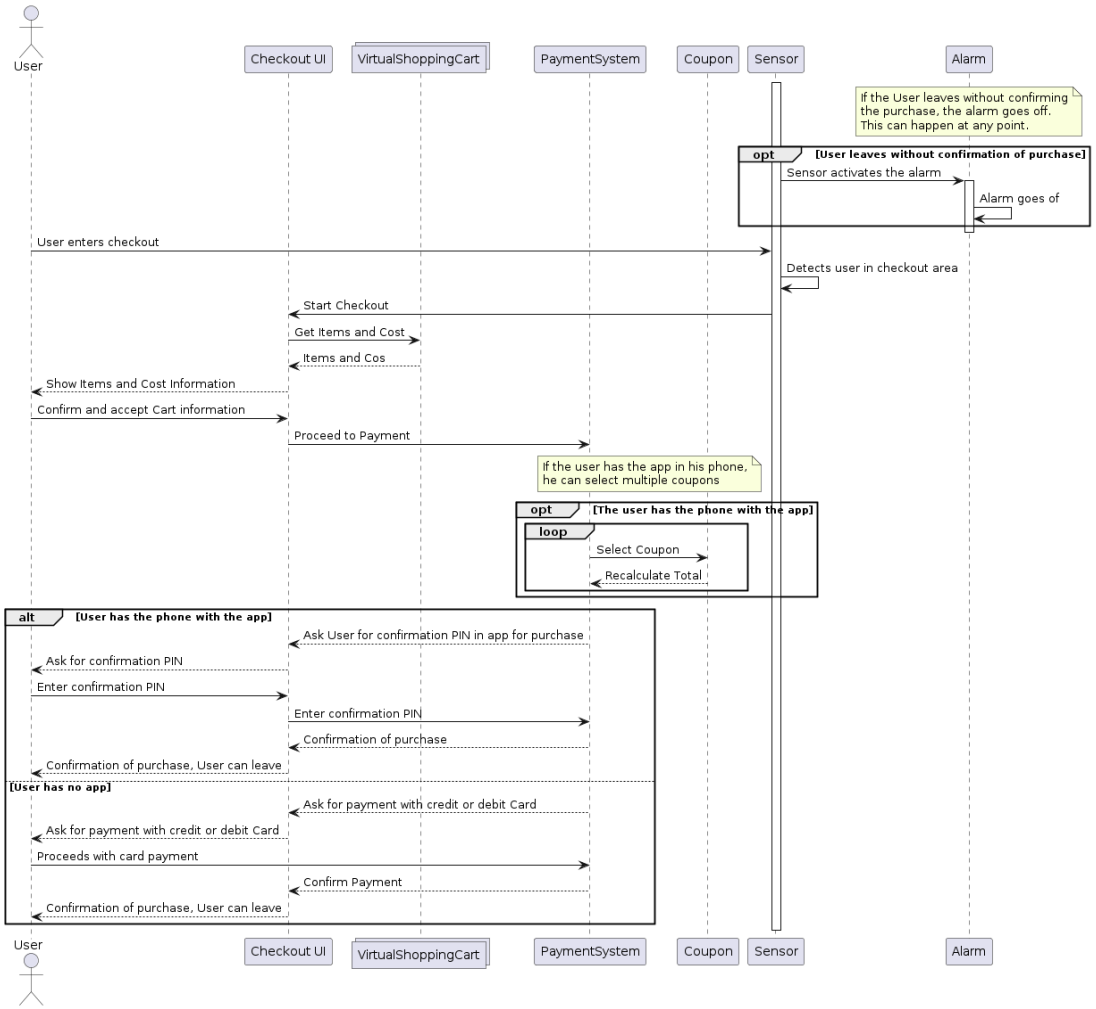
When starting the **checkout process, the information will appear on the Checkout UI about all the items and the total price of the purchase**, and the **user will be prompted to confirm that the items and price are correct**.

When confirmed, proceed to payment.

Before the actual payment, if the user is in the app, he can add coupons to his purchase, as he is connected to his account.

Then, if **the user is in the app**: **confirm** the purchase **with a PIN on the mobile phone** (we can assume the payment method has already been chosen and verified).

Otherwise, **if the user does not have the app**, complete the **purchase using a credit card on the device in the cart**.



4. Use cases

1. **Adding an item to the cart**:
    - Actor: Shopper
    - Description: The shopper places an item into the shopping cart.
    - Preconditions:
        i. The shopper is logged into the system.
        ii. The item to be added is available for purchase.
    - Postcondition:
        i. The item is successfully added to the shopping cart.
        ii. The running total reflects the addition of the item's price.
        iii. The shopping cart contents display shows the newly added item along with any previously added items.
    - Principal Path:
        i. Shopper places an item into the cart.
        ii. System detects the item and updates the running total and cart contents display.

2. **Walking out of the store (checkout)**:
    - Actor: Shopper
    - Description: The shopper is ready to leave the store and confirms the purchase.
    - Preconditions:
        i. The shopper is logged into the system.
        ii. The shopper has completed their shopping and is ready to leave the store.
        iii. The shopper's cart contains the items they intend to purchase.
        iv. The shopper has a valid payment method associated with their account.
    - Postconditions:
        i. The shopper's purchase is successfully processed, and payment is authorized.
        ii. The transaction is finalized, and the purchased items are officially owned by the shopper.
        iii. The shopper exits the store without any security alarms being triggered.
    - Principal Path:
        i. Shopper confirms their intent to purchase and initiates the checkout process by passing the checkout area.
        ii. System prompts the shopper to confirm the payment method and security measure (e.g., PIN).
        iii. Shopper confirms payment.
        iv. System processes the payment and finalizes the transaction.
        v. Shopper receives confirmation of purchase.
    - Exception Path:
        i. Shopper confirms their intent to purchase and initiates the checkout process by passing the checkout area.

        ii. System prompts the shopper to confirm payment method and security measure (e.g., PIN).
        iii. Shopper does not confirm the payment.
        iv. An alarm goes off.
3. **Remove Item from Cart**:
    - Actor: Shopper
    - Description: The shopper removes an item from the shopping cart.
    - Preconditions:
        i. The shopper is logged into the system.
        ii. The shopping cart contains at least one item that the shopper intends to remove.
    - Postconditions:
        i. The specified item is successfully removed from the shopping cart.
        ii. The running total is recalculated to reflect the removal of the item.
        iii. The cart contents display is updated to reflect the removal of the item, ensuring accurate representation of the remaining items in the cart.
    - Principal Path:
        i. Shopper removes an item from the cart.
        ii. System updates the running total and cart contents display accordingly.
4. **View Cart Contents and Tota**l:
    - Actor: Shopper
    - Description: The shopper wants to see the current contents of their shopping cart and the total cost.
    - Preconditions:
        i. The shopper is logged into the system.
        ii. The shopper has access to the app or device attached to the cart
    - Postconditions:
        i. The System successfully displays the current contents of the shopper's shopping cart and the total cost of all items.
    - Principal Path:
        i. Shopper access the app or device attached to the cart.
        ii. System displays the list of items in the cart and the running total.
5. **Membership Discounts and Coupons**:
    - Actor: Shopper
    - Description: The system applies membership discounts or electronic coupons to shopper’s purchase.
    - Preconditions:
        i. The shopper is logged into the system.
        ii. The shopper has eligible membership discounts or electronic coupons associated with their account.
    - Postconditions:
        i. The system successfully applies any eligible membership discounts or electronic coupons to the shopper's purchase.
        ii. The total cost of the shopper's purchase is updated to reflect the discounts or coupons applied.
    - Path:
        i. Shopper selects items for purchase and adds them to the cart.

    ii. System applies relevant coupons based on the shopper's available coupons and membership status.
    iii. System updates the total cost accordingly.
6. **Item Lookup**:
    - Actor: Shopper
    - Description: The shopper wants to locate an item in the store.
    - Preconditions:
        i. The shopper is logged into the system.
    - Postconditions:
        i. The system successfully provides information on the aisle where the item is located to the shopper.
    - Path:
        i. Shopper access the item search feature on the app or cart.
        ii. Shopper inputs the item name or selects from a menu.
        iii. System provides information on the aisle where the item is located.

5. Quality attributes

5.1 Availability

- **Meaning:**

  The system needs to maintain a high level of availability to ensure customers can shop seamlessly during operational hours. If this quality attribute fails, we risk losing customers and, consequently, revenue.
- **Acceptable level:**

  The system's responsiveness should align with the scale of shopping events or foot traffic. During periods of high shopping volumes, particularly peak hours or sales events, the system must efficiently handle the increased load. Specifically, it should detect when an item is added to or removed from the cart within a couple of seconds, ensure checkout completes within 3 to 5 seconds, and bind the application to a shopping cart within 2 to 3 seconds. This ensures a seamless shopping experience even during peak periods, enhancing customer satisfaction and operational efficiency.
- **Importance:**
    - Failing to provide an available service can have a negative impact on customer satisfaction and revenue. As such, this quality attribute is of utmost importance for the Automated Smart Shopping Cart system.
- **Architectural Strategy**
    - The architecture leverages a network of sensors adept at detecting critical events within the store environment, ranging from item manipulation to user presence and store exits. This swift recognition of events enables the system to promptly update the shopping cart and initiate essential processes, effectively minimizing delays and ensuring

uninterrupted operation. Such real-time event detection forms the backbone of the architecture, bolstering its availability and reliability for users.
    - Furthermore, the architecture is designed to accommodate replication across its various components, fostering redundancy and scalability. Each part of the system can be replicated to distribute workload and mitigate the risks associated with single points of failure. Notably, while replication is feasible for most components, careful consideration must be given to maintaining data consistency, particularly when horizontally scaling the inventory database. However, such scaling measures are expected to be seldom necessary, given that a single store typically hosts only a modest number of customers at any given time, with the request rate rarely exceeding the thousands per second threshold.

5.2 Security

- **Meaning:**
    - Maintaining a secure system entails ensuring it's impenetrable to malicious attacks from individuals with ill intent, whether they aim to steal data/products or disrupt services. Security, therefore, encompasses the system's ability to withstand such threats.
- **Acceptable level:**
    - The system must effectively handle all transactions with utmost care, especially since sensitive information such as payment details should never fall into the hands of attackers. Additionally, it should detect when an individual attempts to steal products.
- **Importance:**
    - Security is paramount for the Automated Smart Shopping Cart system as it deals with sensitive customer information and financial transactions. A breach in security could lead to severe consequences, including financial losses, damage to reputation, and legal repercussions. Therefore, robust security measures are essential to maintain trust and confidence among customers and stakeholders These measures extend beyond safeguarding data integrity to include preventing unauthorized transactions, such as individuals attempting to pay with stolen phones, and detecting potential theft incidents, such as exiting without completing payment.
- **Architectural strategy**
    - The architecture prioritizes security through several key measures. Firstly, the payment service enhances transaction security by requiring a PIN during checkout, adding an extra layer of authentication to protect payment information. Additionally, an exit sensor triggers an alarm if a customer attempts to leave the store without completing payment, deterring theft and unauthorized exits.
    - Furthermore, to safeguard data integrity and confidentiality, all messages exchanged within the system are encrypted. This

encryption ensures that sensitive information such as payment details remains protected from unauthorized access or tampering, bolstering overall system security. Together, these measures work cohesively to ensure the security of transactions, prevent unauthorized access, and safeguard sensitive data within the system.

5.3 Reliability

- **Meaning:**
  - Reliability pertains to the consistent and predictable performance of the Automated Smart Shopping Cart system, both in typical and challenging conditions. It focuses on minimizing errors and failures to uphold uninterrupted service delivery.
- **Acceptable level:**
  - When adding or removing items from a shopping cart, the system is expected to ensure accuracy and precision, preventing any inadvertent addition or removal of incorrect items. Furthermore, the mobile application should consistently pair with the nearest and anticipated shopping cart, always presenting the accurate total amount to users. While payment failures may occur, the system must guarantee that erroneous payments are never processed, maintaining integrity and reliability in financial transactions.
- **Importance:**
  - Reliability is of paramount importance for the Automated Smart Shopping Cart system as it directly impacts customer trust and satisfaction. A reliable system not only prevents costly errors but also enhances customer confidence in the shopping experience. By upholding reliability, the system mitigates the risk of financial setbacks and reinforces its reputation as a dependable solution for users.
- **Architectural strategy**
  - To enhance payment accuracy and security, the system utilizes external payment services, requiring only a PIN for authentication during transactions. Sensors play a critical role in binding customers using the mobile application to specific shopping carts and associating items with carts. This approach ensures the verification of user actions directly through sensor data, minimizing the reliance on user input via the UI, which may be prone to errors or misrepresentation.

5.4 Usability

- **Meaning:**
  - Usability in the context of the Automated Smart Shopping Cart system refers to the seamless and intuitive interaction experience it offers to users. It encompasses how easily customers can navigate the system, add or remove items from their carts, and complete transactions efficiently and intuitively, both through the mobile application and the physical interface.

- **Acceptable level:**
    - The system aims for exceptional usability, ensuring that users can effortlessly interact with the shopping cart and related interfaces. This involves intuitive navigation, clear prompts, and responsive feedback mechanisms. The mobile application and on-cart interfaces should be designed with user convenience in mind, enabling swift and error-free interactions to enhance the overall shopping experience.
    - Specifically, users should be able to swiftly complete common tasks, such as adding items to their carts, viewing their selections, and making payments, with a completion time under 5 seconds. Additionally, the system strives for an error rate under 1%, minimizing user mistakes and ensuring a smooth shopping experience. Furthermore, satisfaction surveys should yield a score of at least 4 out of 5, indicating a high level of user satisfaction with the system's usability.
- **Importance:**
    - Usability is paramount for the success of the Automated Smart Shopping Cart system as it directly influences user satisfaction and adoption. A highly usable system reduces friction in the shopping process, leading to increased efficiency, customer engagement, and loyalty. By prioritizing usability, the system can attract and retain users, ultimately driving its success in the competitive retail landscape.
- **Architectural strategy**
    - A unified user interface serves as a central hub, offering clients a seamless interaction with the Automated Smart Shopping Cart system. This interface consolidates various functionalities, allowing users to effortlessly navigate through the shopping experience. By presenting a cohesive and intuitive interface, users can easily browse products, manage their carts, and complete transactions, enhancing overall usability and user satisfaction. Moreover, the integration of sensors within the system enables automatic recognition of user actions that mirror those in traditional stores. These sensors detect and interpret actions such as item selection, cart manipulation, and exit events, seamlessly translating them into system responses. This automated recognition not only streamlines the shopping process but also enhances efficiency and convenience for users, mirroring the familiar experience of shopping in physical stores.
    - Furthermore, pre-configured payment methods contribute to a frictionless checkout experience, ensuring swift and hassle-free transactions while maintaining security standards. By offering pre-configured payment options, such as saved credit cards, users can complete payments with minimal effort and in a timely manner, as permitted by security protocols.