Software Design Description

Version 1.0

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Table of Contents

List of Figures

List of Tables

Revision History

Version	Date	Explanation
1.0	24.06.2020	First release of the fully completed Software Design Description document.

Table 1: Change History

1 Introduction

1.1 Purpose of the system

Amazon Go is a cashier-less-store concept implementation that allows customers to pick out what they need and simply walk out the door without waiting in lines or check-outs. With this concept, Amazon Go aims to decrease the employee cost (fewer cashiers, fewer store staff), inventory checking costs, and save customers more time.

1.2 Scope

In the scope of this system,

- Customers can make their shopping without waiting at checkout or paying at checkout. In order to succeed this, customers shall download the Amazon Go mobile application to their Android, iPhone, and Windows Phone smartphones.

- The main interaction of customers during the shopping with the system is through the application on their phones, but the system has also a web interface for checking the past receipts, new products, personal information, and so on.

- Store managers and store workers use the same web application but with different GUI and privilege levels.

- In stores, there are turnstiles that are opened when customers scan their QR codes that are generated uniquely in the mobile application. During their shopping, cameras and sensors track the customers to identify products in their baskets. Therefore the system has a lot of sensors, cameras, and management systems.

- Amazon Go system also uses database services for three purposes:

  - Personal data of the customers such as receipts, saved credit cards, etc., store information, and worker information
  - Product details
  - "Can Not Decide" event details (for more explanation refer to Glossary section)

- Tracking customers in the shopping is done with the help of computer vision, sensor fusion, and various machine learning technologies. In the case of the "Can Not Decide" event (for more explanation refer to Glossary section) which the system cannot define which product is selected, Amazon Go IT staff will intervene and detect the product.

1.3 Stakeholders and their concerns

In broad terms, Amazon Go is a store and take payments from their customers. In addition to that, the system gathers personal data in order to operate more efficiently.

Customers: Customers are people that make shopping in the store. Their main concern is quick shopping, the privacy of their data, accuracy of their transactions. Since Amazon Go requires customers to save at least one credit card to their Amazon account in order to use the system, they are worried about the credit card information that is stored in the system. Also, during shopping, the camera system

follows their steps, observes the products they choose. All of these records are in an online platform, therefore they want the system to block unauthorized access to them. Lastly, the system automatically withdraws the total price of chosen products, so customers want to ensure that the right amount of money was withdrawn from their cards.

Store Managers: Store managers are authorized users of the system. Their main concern is the management of their stores. They want to make some inventory operations like applying discounts, submitting new products in the system. Also, they want to check the status hardware that is located in the store they manage. Therefore, they want a simple management interface that presents status and modification options for database and hardware in the store.

Store Workers: Store workers are less authorized users of the system. They are simply workers of the smart store and their concerns are helping customers that are not a member of the system and arranging the disorganized products. Therefore, they want a simple interface that allows to do store operations.

System Developers: System developers are members of the team that is responsible for the development of the Amazon Go system. Their main concern is designing and developing a system that has high fault tolerance. They highly need a lot of process documents that describe the system.

Amazon Go IT Staff: They are also members of a different team that is responsible for responding to CND events, solving CND events, and checking logs of the system. Therefore their concern is a comprehensive interface for managing the whole system.

Amazon: Amazon is the customer and investor of the smart store concept. It is the main e-commerce company and its concern is expanding the commercial model using a smart and cashier-less store concept.

2 References

This document is prepared according to specifications of the below document:

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3 Glossary

Term	Definition
Customer	A person who uses the smart store.
IT Staff	Information Technology Staff that handles CND events and maintenance
Store Manager	The authority of a store.
Store Worker	General workers work in the store. They do simple market operations
CND Event	Means Can Not Decide Event. The system is not able to detect some situations. In this case, these events are called CND events and they are sent to IT Staff.
DB Service	Means Database service. It is provided by Amazon Relational Database Service.
Commercial off-the-shelf system	Existing products that can be supplied by the market. They are integrated into larger systems and provides the necessary functions.

Table 2: Glossary

4 Architectural Views

4.1 Context View

In this viewpoint, the context of the system is explained in detail. The context diagram consists of actors in the system and their roles against the system. User case diagram and all use cases in it are explained with its actors, description, preconditions, flows, and postconditions to make clear their context.
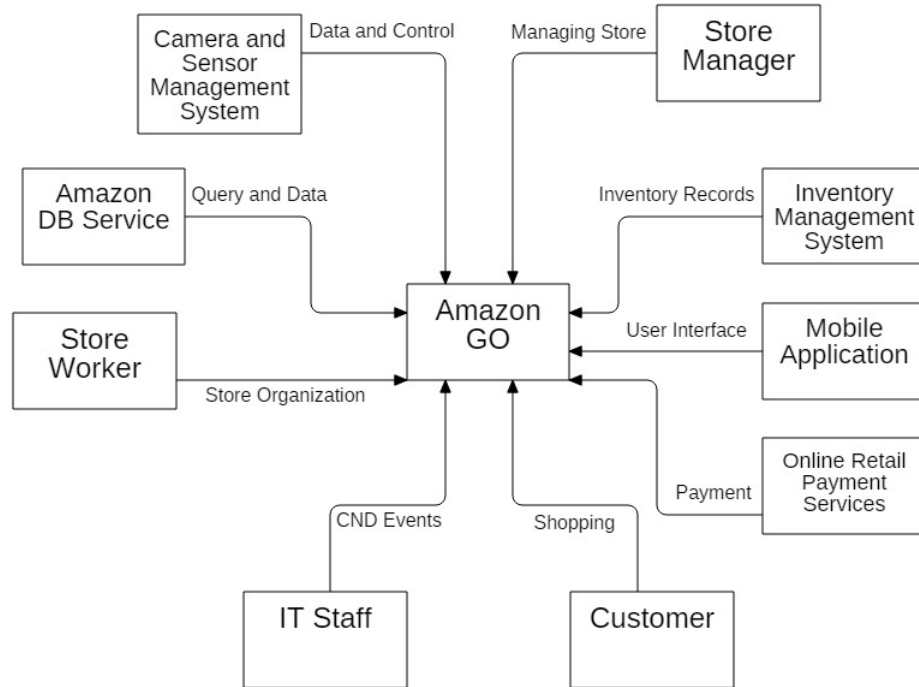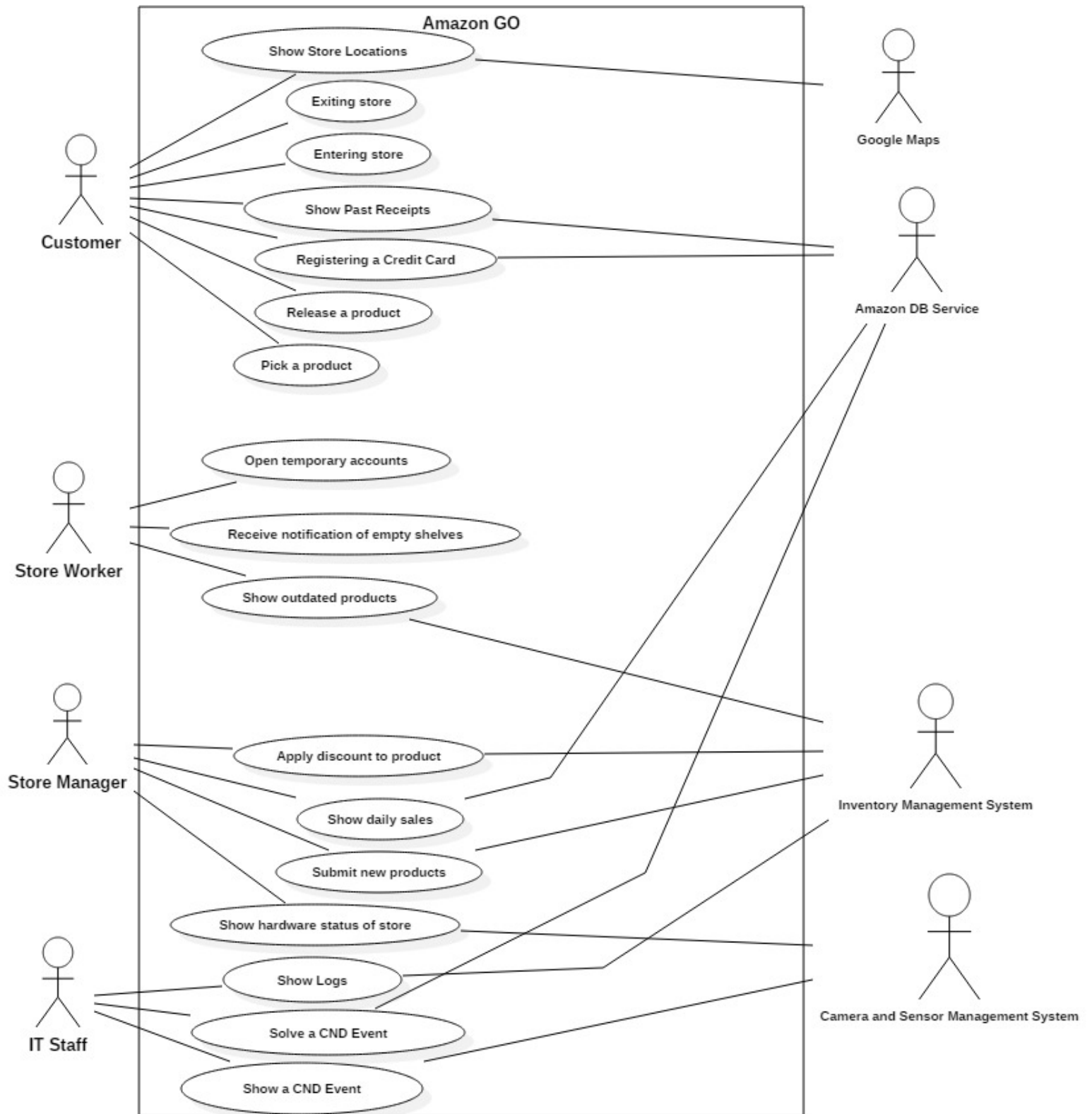

Figure 1: Context Diagram

Figure 2: Use Case Diagram

Use case name	Show Store Locations
Actors	Customer, Google Maps
Description	Customers may see the location of themselves and the locations of all stores on the world map. Also, the system shall show the nearest store.
Data	Location of the customer
Preconditions	Customer shall login the system, the location service of his/her phone should be opened, and required permissions should be given the application.
Stimulus	Customer touches **Show Stores** button.
Basic Flow	Step 1: Customer opens the mobile application Step 2: Customer signs in his/her account Step 3: Customer touches the **Show Stores** button Step 4: His/Her location is sent to the server Step 5: System identifies the QR code and the customer. Step 6: Customer sees the location of himself/herself, nearest store, and other stores on the world map.
Alternative Flow #1	Step 2: If the customer doesn't give the permission of location service or open it, a warning message appears in the screen.
Exception Flow	Step 6: If an error occurs, a message appears in the screen.
Postconditions	The map is cached in the application of the customer.

Table 3: Show Store Locations

Use case name	Exiting store
Actors	Customer
Description	Tourniquets that allow one-way pass is opened automatically when a customer wants to leave the store. Therefore, the system must determine which customer goes out of the store, and the total price of his/her shopping is withdrawn.
Data	Information of customer exiting from the store
Preconditions	Customer shall be registered to the system, enter the store.
Stimulus	Customer passes through the tourniquet and goes outside of the store.
Basic Flow	Step 1: Customer comes to the tourniquets. Step 2: The tourniquet opens for the customer to go outside. Step 3: The tourniquet closes to disallow the entrance through it. Step 4: The total price of products bought by the customer is withdrawn from the credit card of the customer saved in the system before.
Alternative Flow	-
Exception Flow	Step 4: If any error occurs, the event is logged with customer and products information
Postconditions	After the customer exits from the store, the tourniquet closes, the customer is charged with the products bought and the total price is withdrawn from the credit card of the customer saved in the system before. Also, receipt of the customer is recorded in the system.

Table 4: Exiting store

Use case name	Entering store
Actors	Customer
Description	When a customer enters the store he/she scans his/her unique QR code received from the mobile application. System identifies the QR code and opens the turnstiles.
Data	Customer's QR code
Preconditions	Customer shall be registered to the system, customer shall register at least one credit card and receive a QR code.
Stimulus	QR reader on turnstiles reads the QR code of customer.
Basic Flow	Step 1: Customer opens the mobile application Step 2: Customer signs in his/her account Step 3: Unique QR code is shown in the interface Step 4: Customer scans the QR code into the tourniquets placed in entrance of the store Step 5: System identifies the QR code and the customer. Step 6: The tourniquet opens, and the customer can get in the store. System tracks the customer
Alternative Flow #1	Step 2: If the customer has not signed the system yet the sign-in interface is shown. If the customer opened the application for the first time, a quick introduction is also shown
Alternative Flow #2	Step 3: If the customer hasn't registered any credit card information, or chosen any main payment method, payment method selection is shown
Exception Flow	Step 6: If an error occurs in turnstiles, store workers are notified.
Postconditions	The system opens the turnstiles, starts tracking the customer, closes them after passing the turnstiles.

Table 5: Entering store

Use case name	Show past receipts
Actors	Customer, Amazon DB Service
Description	After shopping of a customer, information containing names and amounts of products bought, total amount paid, date of shopping and the place of store are saved in Amazon DB Service and showed in the customer's account in the user interface.
Data	Customer information, Customer's credit card information, date of shopping, address of store where shopping is done, names, amounts and prices of products bought, and total amount paid
Preconditions	-
Stimulus	Customer opens Receipts page
Basic Flow	Step 1: Customer opens the Receipts page from his/her account. Step 2: Database service queries and sends the information about the customer. Step 3: Past receipts are displayed in the interface.
Alternative Flow	Step 3: If the customer has not done any shopping yet, the database service returns NULL, and the message "You have no available receipts to review" message is displayed in the interface.

Exception Flow	If a DB error returns, it is saved in log files, and nothing is displayed in the interface.
Postconditions	Receipts are shown in the customer interface.

Table 6: Show past receipts

Use case name	Registering a credit card
Actors	Customer, Amazon DB Service
Description	A customer can save his/her credit cards to system.
Data	Credit card information of the customer
Preconditions	Customer shall be signed in the system.
Stimulus	Customer clicks the **Add another payment method** button.
Basic Flow	Step 1: Customer opens application and signs in the system. Step 2: Customer clicks the settings section and choose Payment cards. Step 3: Customer must fill his/her credit card information in order to use the system. Step 4: Credit card information is saved in the database.
Alternative Flow	-
Exception Flow	If the customer does not write true credit card information, system warns the customer to give the correct info and wrong info is not saved into the database.
Postconditions	Customer's credit card information is updated.

Table 7: Registering a credit card

Use case name	Release a product
Actors	Customer
Description	The functions in Amazon GO stores recognizes when a customer releases a product after he/she picks it. This system identifies which product is released and which customer does it by using various machine learning techniques. After the identification, the product left to the shelves is deleted from the customer's basket in the mobile application.
Data	Information of customer who releases the product, Product released by the customer
Preconditions	Customer has entered the store, identified by the system, and picked a product
Stimulus	Customer releases the product which he/she has selected
Basic Flow	Step 1: Customer enters the store. Step 2: The system starts to watch the customer. Step 3: The customer walks around the store. Step 4: The customer chooses a product and picks it up. Step 5: The system identifies the product. Step 6: The system provides the product to be added to the customer's basket. Step 7: The customer changes the decision and releases the product. Step 8: The system identifies which product is released.

	Step 9: The system provides the product to be deleted from the customer's basket.
Alternative Flow	Step 9: After deleting it from the basket, if the customer doesn't release the product into its previous location its location is sent to the store worker as disorganized product
Exception Flow	Step 8: If the product released is not recognized by the system, it is identified as a CND event, and is reported to IT Staff immediately.
Postconditions	The customer's basket is updated.

Table 8: Release a product

Use case name	Pick a product
Actors	Customer
Description	The functions in Amazon GO stores recognizes when a customer picks a product. This system identifies which product is selected and which customer picks it by using various machine learning techniques. After the identification, the product wanted to be bought is added into the customer's basket in the mobile application.
Data	Information of customer who picks the product, Product selected by the customer
Preconditions	Customer has entered the store, and he/she is identified by system
Stimulus	Customer selects a product from shelves and lifts it
Basic Flow	Step 1: Customer enters the store. Step 2: The system starts to watch the customer. Step 3: The customer walks around the store. Step 4: The customer chooses a product and picks up it. Step 5: The system identifies the product. Step 6: The system provides the product to be added to the customer's basket.
Alternative Flow	-
Exception Flow	Step 5: If the product is not recognized by the system, it is identified as CND event, and is reported to IT Staff immediately
Postconditions	The customer's basket is updated.

Table 9: Pick a product

Use case name	Open temporary accounts
Actors	Store worker
Description	In order to enter the store and do shopping, customers shall be registered in the system. However, for a customer who has not an Amazon account and wants to do shopping in Amazon GO stores, a new, temporary account is opened by the store worker.
Data	Information of customer
Preconditions	A customer who will be registered has not had an account before.
Stimulus	Store worker clicks **Open temporary account** button

Basic Flow	Step 1 – A customer comes to the store.
	Step 2 – He/she asks for help from a store worker to get in the store.
	Step 3 – The store worker opens a temporary account for the customer.
	Step 4 – The store worker fills out the information of the customer.
	Step 5 - System tracks the customer with this information and relates the picked product to this account
Alternative Flow	-
Exception Flow	Any error in the system will be recorded in error logs.
Postconditions	The customer enters the store with the temporary account and the account is deleted automatically after he/she leaves the store.

Table 10: Open temporary accounts

Use case name	Receive notification of empty shelves
Actors	Store worker
Description	When a shelf becomes empty after customers' shopping, the system can detect it and informs the store workers so that new products are placed on the shelf. After the store worker places the products on the shelf, the system can again detect it and products on the shelf are approved by the store worker.
Data	Location of the empty shelf on the store and which product belongs to that shelf
Preconditions	-
Stimulus	The shelf becomes empty
Basic Flow	Step 1 – Customers buy products on a shelf.
	Step 2 – The shelf becomes empty.
	Step 3 – The system detects the empty shelf.
	Step 4 – The notification containing the information about which shelf is empty and which products will be placed on that shelf is given to store workers.
Alternative Flow	-
Exception Flow	Step 4: Any error in the system will be recorded. The sensor and camera data is also added to this log file.
Postconditions	Notification is sent to store worker, he/she puts the products to the shelves and approved by both system and store worker

Table 11: Receive notification of empty shelves

Use case name	Show outdated products
Actors	Store worker, Inventory management system
Description	Products are saved in inventory management system with their expiration date. If a product becomes outdated, it is notified by the inventory management system to store workers.
Data	Name and place of the outdated product on the store
Preconditions	Outdated product is on the store
Stimulus	The expiration date of a product passes.
Basic Flow	Step 1: A product becomes expired.

	Step 2: Inventory management system sends a notification to store workers. Step 3: Store workers see which product is outdated and where it is on the store.
Alternative Flow	-
Exception Flow	If the product is shown as outdated, but it has been already sold, the store worker reports the IT Staff
Postconditions	The store worker receives the notification of outdated products from the shelves and their locations

Table 12: Show outdated products

Use case name	Apply discount to product
Actors	Store manager, Inventory management system
Description	It is the duty of the store manager to increase the sales in a store. Therefore, the store manager can apply discount to products in his/her store and he/she saves it into Inventory management system.
Data	Product code, and new price of product
Preconditions	Store manager shall sign in his/her account
Stimulus	Store manager clicks the **Apply Discount** button.
Basic Flow	Step 1: Store manager sign in his/her account Step 2: He/She clicks the Discount section in his/her interface Step 3: He/She writes product code and new price, then clicks the **Apply Discount** button Step 4: New price is set, and inventory is updated according to new price.
Alternative Flow	-
Exception Flow	If any error occurs, its details are recorded in system error logs
Postconditions	The new price is updated in inventory, and store manager can see the old and new price of product in his/her interface.

Table 13: Apply discount to product

Use case name	Show daily sales
Actors	Store manager, Amazon DB service
Description	Daily sales of stores are saved in Amazon DB service and can be seen by the store's manager to follow incomes and outgoings of the store.
Data	Daily information of products sold with names and amounts, and total price earned in that day.
Preconditions	Store manager shall sign in his/her account
Stimulus	Store manager clicks the **Show Daily Sales** button.

Basic Flow	Step 1: Store manager sign in his/her account
	Step 2: He/She clicks the **Show Daily Sales** button
	Step 3: Database service queries and sends the information about all sales.
	Step 4: All information of sales is appeared in store manager interface.
Alternative Flow	-
Exception Flow	Any error in the flow is recorded in system error logs.
Postconditions	Daily sales of stores and related information is appeared in store manager interface.

<div align="center">Table 14: Show daily sales</div>

Use case name	Submit new products
Actors	Store manager, Inventory management system
Description	When new products come to the store, store manager shall submit the information of products such as Expiration date, stock etc. into inventory management system.
Data	Amounts, prices and names of the products that come to the store.
Preconditions	Store manager shall sign in his/her account
Stimulus	Store manager clicks the **Submit New Products to Inventory** button.
Basic Flow	Step 1: New products arrive in the store.
	Step 2: Store manager signs in his/her account
	Step 3: He/She clicks the **Submit New Products to Inventory** button, and a product identification form appears
	Step 4: After filling the form, store manager clicks the submit button
	Step 5: Inventory Management System updates stock information of store by using form information.
Alternative Flow	-
Exception Flow	If an error occurs, it is written to error logs.
Postconditions	Inventory management system updates the stock information of store.

<div align="center">Table 15: Submit new products</div>

Use case name	Show hardware status of store
Actors	Store manager, Camera and Sensor Management System
Description	Hardware of a store consists of sensors and cameras connected with their management system and the store manager can see the status of them such as erroneous components, battery powers etc.
Data	Status information of components, and location information of them
Preconditions	Store manager shall sign in his/her account
Stimulus	Store manager clicks the **Show Status of Store** button.
Basic Flow	Step 1: Store Manager signs in his/her account
	Step 2: After login process, he/she clicks the **Show Status of Store** button.
	Step 3: The statuses of cameras and sensors, and locations of them are appeared in the interface

Alternative Flow	-
Exception Flow	Step 3: Store manager shall inform required people regarding an error if there is any.
Postconditions	Hardware status of the store is appeared in Store Manager Interface.

Table 16: Show hardware status of store

Use case name	Show Logs
Actors	IT Staff, Inventory Management System
Description	IT Staff accesses system logs in Inventory Management System.
Data	Logs of system operations like error time, access time, authentication failure, etc.
Preconditions	IT Staff shall sign in his/her account
Stimulus	IT Staff clicks the **Show Logs** button
Basic Flow	Step 1: Any system event details are logged, and kept in database. Step 2: In order to see them, IT Staff clicks the **Show Logs** button and specifies the date. Step 3: All logs of events that are occurred at the specified time is shown in the interface of IT Staff.
Alternative Flow	-
Exception Flow	If an error occurs, the "Database Error" message is shown in the interface.
Postconditions	All events logged are shown in the IT Staff interface.

Table 17: Show Logs

Use case name	Solve a CND Event
Actors	IT Staff, Amazon DB Service
Description	When a CND event occurs, notification of this event is sent to IT Staff. IT Staff solves a CND event, and sends necessary descriptions of event to the system in order to improve training models of computer vision components. Details are saved to Amazon DB Service.
Data	Description of event
Preconditions	System cannot determine a situation and sends to the system to identify what happened in this event.
Stimulus	IT Staff clicks the **Solve CND Event** button
Basic Flow	Step 1: A CND event occurs and system sends notification of this event to IT Staff. Step 2: IT Staff clicks the **Show CND Events** button to see the details of it. Step 3: Sensor and Camera Data related to CND Event is shown in the interface of IT Staff. Step 4: After examining the data, IT staff determines what happens in event. Step 5: IT Staff writes the description of CND event and sends to the system by clicking **Solve CND Event** button.
Alternative Flow	-

Exception Flow	Related error is written to the system logs.
Postconditions	Description of CND event is used by the system to improve the training models. Also, the CND event is deleted from CND Events List.

Table 18: Solve a CND Event

Use case name	Show a CND Event
Actors	IT Staff, Camera and Sensor Management System
Description	Whenever a CND event occurs, notification of this event is sent to IT Staff. IT Staff can see the unsolved CND Events, and data related to these CND Events.
Data	Sensor Data, Camera Data, Event Details
Preconditions	The system cannot determine a situation and saves the details of it in the database.
Stimulus	IT Staff clicks the **Show CND Events** button
Basic Flow	Step 1: A CND event occurs and system sends notification of this event to IT Staff. Step 2: IT Staff clicks the **Show CND Events** button to see the details of it. Step 3: Sensor and Camera Data related to CND Even is shown in the interface of IT Staff.
Alternative Flow	-
Exception Flow	When Sensor and Camera Data cannot be shown by interface, error logs is recorded in DB.
Postconditions	All CND events and related data are shown in the IT Staff interface.

Table 19: Show a CND Event

4.2 Composition View

In the composition view, subsystems, external parts of the system and their interfaces are explained from a top-level point.
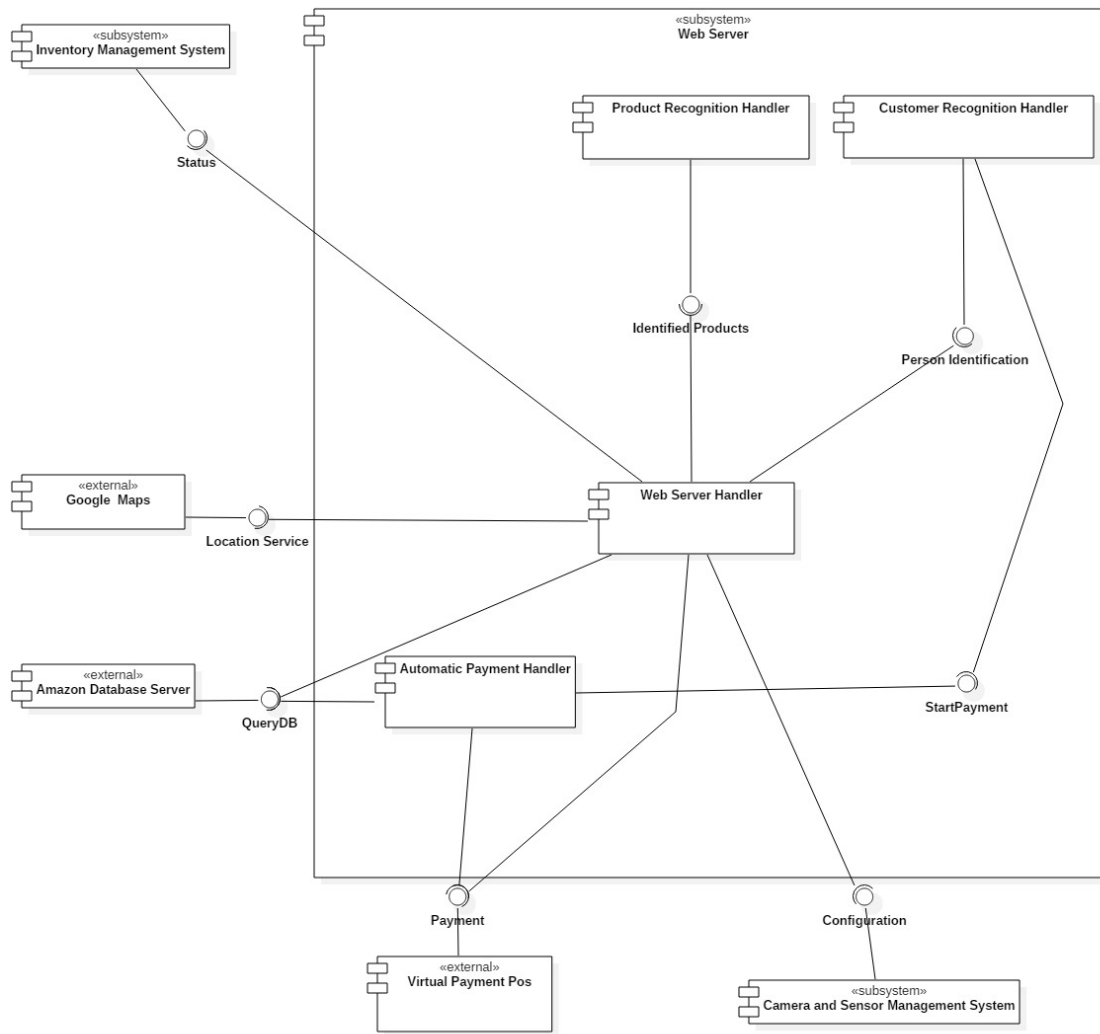
Figure 3: Component Diagram

Design Rationale:

- Web server handler is the main component of the Web Server subsystem. It handles the coming requests. Main duties of this handler are managing store inventory by using Inventory Management System Component, responding customers' and workers' requests, getting information about identified products and customers from Product Recognition Handler and Customer Recognition Handler respectively, handling the configurations of Camera and Sensor Management System and getting data from it, querying Amazon Database Server for internal services, and checking the validity of a customer registered credit card by using Virtual Payment Pos.

- Product Recognition Handler serves Web Server Handler. It recognizes the products picked and released by a customer by using data given from Web Server Handler. The response is an error or identified product information.

- Customer Recognition Handler Component is required for the recognition of people in the store and sending this information to Web Server Handler. It is also used for triggering the Automatic

18

Payment Handler.

- Automatic Payment Handler does the automatic payment by getting the credit card information of a customer who buys something from Amazon Database Server Component and using the payment interface provided by Virtual Payment Pos Component.

- Inventory Management System sends the number and the name of product information to Web Server Handler and Web Server Handler stores new products coming to the store in or removes the products bought from Inventory Management System Component. Also, it manages the system logs.

- Google Maps is an external system and it is used for geographical location purposes like showing the store places on the map.

- External Amazon Database Server component is mainly used for accounting purposes. All customer and worker related data are stored here because Amazon GO system worked with Amazon accounts. Therefore, it is mainly used for identification and authorization of requests.

- Virtual Payment Pos system is used for taking payments from customers' credit cards. It withdraws the desired payment amount from the given card.

- Camera and Sensor Management System component deal with the data of hardware devices in stores and their configurations. It is controlled and requested by Web Server Handler. Its operations are provided just for privileged users.
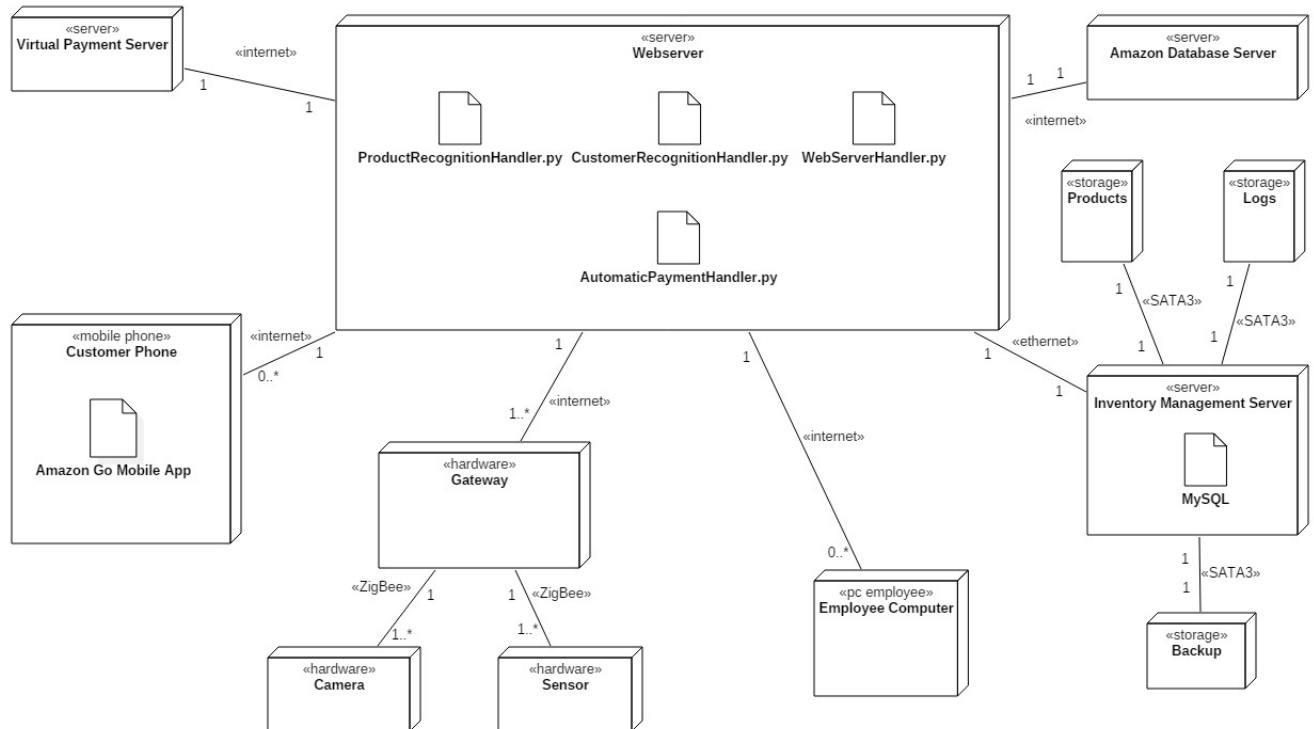

Figure 4: Deployment Diagram

Design Rationale:

- Web Server is developed with Python, and MySQL is used in Inventory Management Server.

- Since user accounts are managed by Amazon Database Server, inventory management server holds products and logs with their backups.

- Customers use Amazon Go Mobile App which is downloaded in their smartphones. All workers reach the system through a computer.

- Virtual Payment Server is used for automatic payments of the system.

- Cameras, Sensors, and their gateways are commercial off-the-shelf (COTS) systems. They use the ZigBee protocol for a local area network.

- Inventory Management System is composed of three main storages:

  - Names, prices, expiration days, and amount of products are stored in Products Storage.
  - System logs are stored in Logs Storage.
  - The backup of these two is stored in Backup Storage.

- Storage is done with SATA3 because it provides the fastest connection in the SATA series.

4.3   Information View

In this view, the details of database model is given with the defined create, read, update and delete operations on them in a class diagram. Also, interface class diagram is given to explain the data, operations and relations between them.
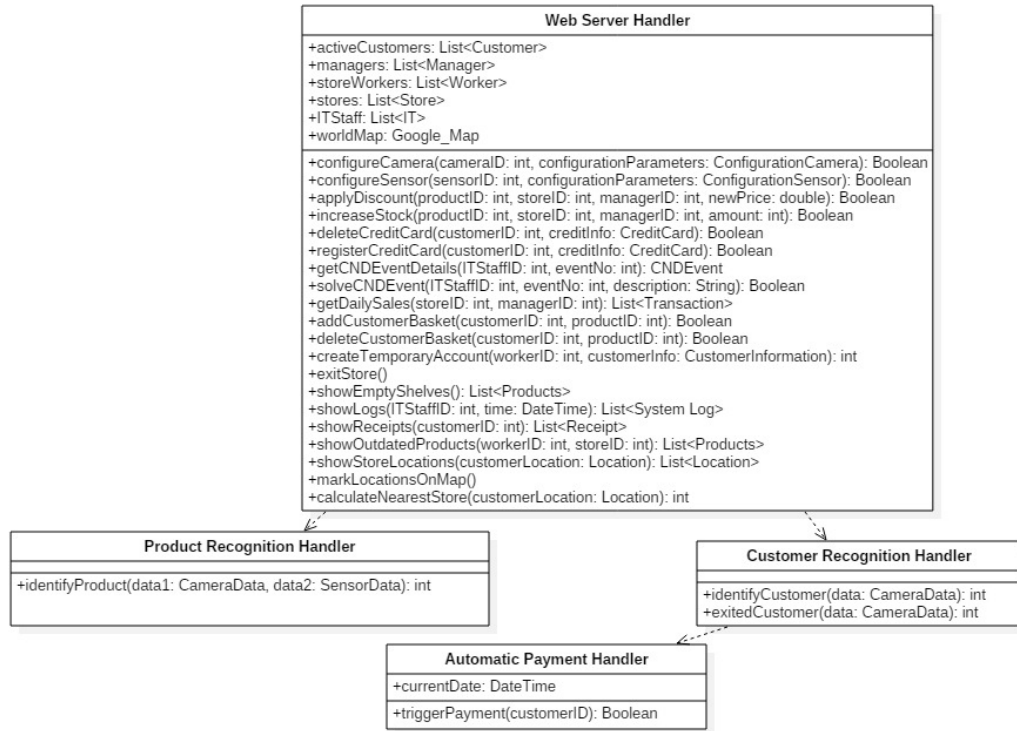
4.3.1 Interfaces

Figure 5: Interface Class Diagram

Operation	Description
configureCamera	This operation allows configuration of selected camera.
configureSensor	This operation allows configuration of selected sensor.
applyDiscount	Store manager can apply discounts to selected product for his/her store and save it in Amazon DB service.
increaseStock	When new products arrive in the store, they are saved into the inventory management system with this operation by store manager.
deleteCreditCard	Customers can delete registered credit cards from their mobile applications using this operation.
registerCreditCard	Customers can save new credit cards into their mobile applications using this operation.
getCNDEventDetails	IT staff can see the details about a selected CND event with this operation.
solveCNDEvent	After IT staff solves a CND event, he/she can save it to the system with this operation.
getDailySales	Store manager can see daily sales of his/her stores using this operation.
addCustomerBasket	After this operation, a new product is added to the shopping basket in the mobile application of the customer who picks up the product.

deleteCustomerBasket	When customer releases the product that he/she holds, the product is deleted from his/her shopping basket in the mobile application with this operation.
createTemporaryAccount	This operation allows store workers to open temporary accounts for customers who has not registered in the system to do shopping.
exitStore	This operation is used when a customer exits, it triggers the web server.
showEmptyShelves	If a shelf is empty, the notification is sent to the store worker with this operation.
showLogs	IT staff can see the system logs for a specific time with this operation.
showReceipts	This operation allows customers to see their own receipts in their interfaces using this operation
showOutdatedProducts	Store worker can see the list of outdated products using this operation in his/her store.
showStoreLocations	Customer can see the locations of store in the mobile application using this operation.
markLocationsOnMap	This function marks the received locations on worldMap.
calculateNearestStore	This function determines the nearest store to the customer.
identifyProduct	A product picked up by a customer is identified using this operation.
identifyCustomer	Identity of customer is detected by using this operation.
exitedCustomer	Information of which customer going out of the store is received from this operation and it causes to withdraw the cost.
triggerPayment	It triggers the payment of specified customer.

Table 20: Operation Descriptions

Operation	Inputs	Outputs	Exceptions
configureCamera	-Camera ID -Configuration Parameters	True if configuration is done otherwise false	-Camera ID is not valid -Camera and Sensor Management System connection error occurs.
configureSensor	-Sensor ID -Configuration Parameters	True if configuration is done otherwise false	-Sensor ID is not valid -Camera and Sensor Management System connection error occurs.
applyDiscount	-Product id -Store id -Manager id -New price	True if discount is applied to the product in the store by the manager, otherwise false	-Product id is not valid -Store id is not valid -Manager id is not valid -New price must be less than the current price -Database connection error occurs -Inventory management system connection error occurs

increaseStock	-Product id -Store id -Manager id -Amount of new product	True if the amount of the stock is increased, otherwise false	-Product id is not valid -Store id is not valid -Manager id is not valid -Amount of new product can not be negative -Inventory management system connection error occurs -Database connection error occurs
deleteCreditCard	-Customer id -Credit info	True if deletion operation is done otherwise false	-Database connection error occurs
registerCreditCard	-Customer id -Credit info	True if registration operation is done otherwise false	-Customer id is not valid -Credit card id is not valid -Name on the credit card is not valid -CVV of the credit card is not valid -Expiration date of the credit card has passed -Database connection error
getCNDEventDetails	-IT Staff id -Event no	Information about CND event including its details	-IT staff id is not valid -Event no is not valid -Database connection error occurs
solveCNDEvent	-IT staff id -Event no -Description of the event	If the CND event is solved and saved, it is true otherwise false	-IT staff id is not valid -Event no is not valid -Database connection error occurs
getDailySales	-Store id -Manager id	Names, amount and prices of products saled on that day	-Store id is not valid -Manager id is not valid -Database connection error occurs -Inventory management system connection error occurs
addCustomerBasket	-Customer id -Product id	True if product is added to the customer's basket otherwise false	-Product id is not identified -Customer id is not identified -Internet connection error occurs -Database connection error occurs

deleteCustomerBasket	-Customer id -Product id	True if product is removed from the customer's basket otherwise false	-Product id is not identified -Customer id is not identified -Internet connection error occurs -Database connection error occurs
createTemporaryAccount	-Worker id -Temporary account information of customer	A temporary customer id is returned	
exitStore			-Internet connection error occurs
showEmptyShelves		List of finished products in the store	-"There are no empty shelves" error occurs
showLogs	-IT Staff id -Specified Time	List of System Logs for given time.	-Database connection error occurs
showReceipts	-Customer id	List of Receipts	-Database connection error occurs -"You have no available receipts to review" error occurs
showOutdatedProducts	-Store ID -Worker ID	List of Products that are outdated in a store	-Inventory management system connection error occurs -Database connection error occurs
identifyProduct	-Data belonging to camera -Data belonging to sensor	Id of product identified by camera and sensor	-Camera and sensor management system connection error occurs
showStoreLocations	-Customer Location	List of locations of stores	-Google Maps API Error occurs -Location Service of customer error occurs
markLocationsOnMap			-Map corruption error occurs
calculateNearestStore	-Customer Location	The nearest store ID	-Floating point error -Arithmetic operation error
identifyCustomer	-Camera data	Customer id identified by the camera	-Camera and Sensor Management System connection error occurs
exitedCustomer	-Camera data	Customer id identified by the camera	-Camera and Sensor Management System connection error occurs
triggerPayment	-Customer id	True if the payment is taken otherwise false	-Online retail payment service connection error occurs -Database connection error occurs

Table 21: Operation Design

Design Rationale:

- Web Server Handler is the main controller that handles the coming requests from customer mobile application, IT Staff interface, manager interface and store worker interface.

- Almost in all operations, the authorization is checked. For instance, a manager cannot apply a discount to a product that doesn't belong to his/her store. It is checked by using Manager and Store id in the requests.

- Automatic Payment Handler is triggered by Customer Recognition Handler whenever a customer exits the store, and it saves the transaction to the database.

- Recognition events are done by Product Recognition Handler and Customer Recognition Handler.
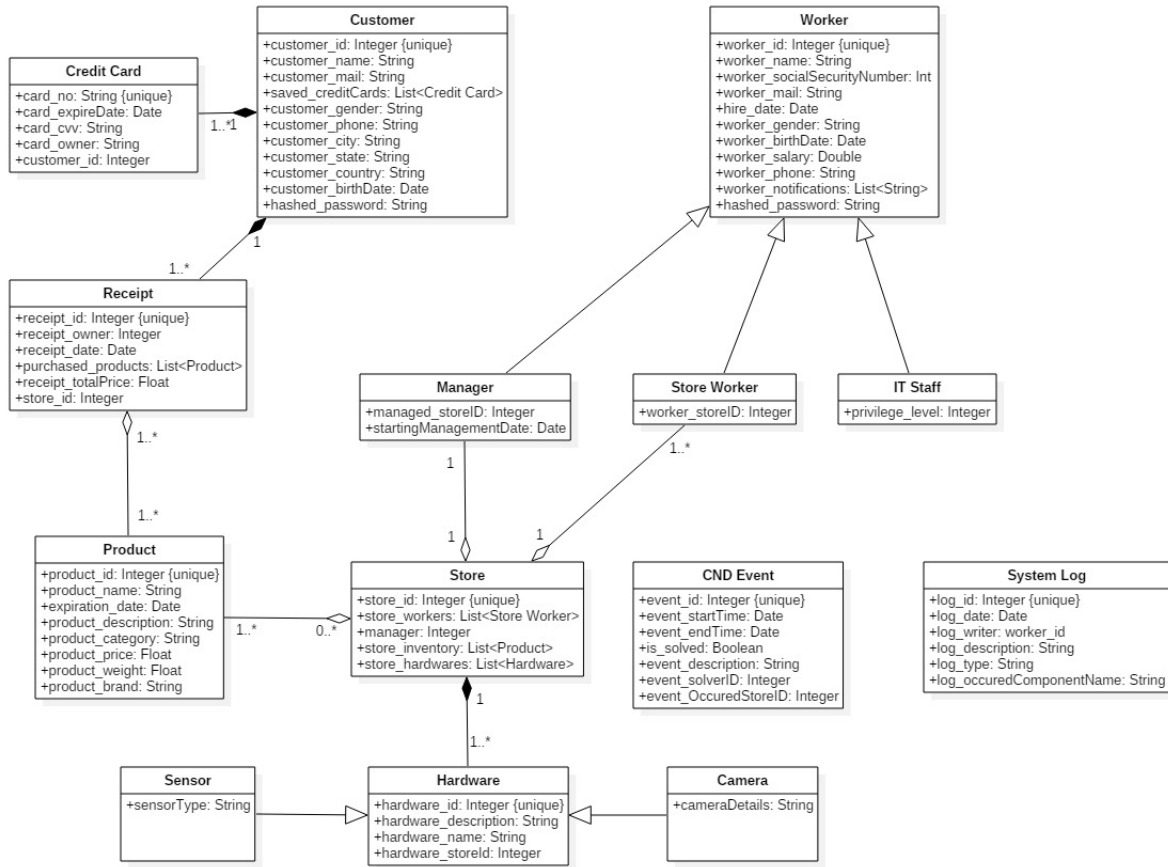
4.3.2 CRUD Operations

Figure 6: Database Class Diagram

Operation	CRUD Operations
applyDiscount	Create: Read: Product, Store, Manager Update: Product Delete:
increaseStock	Create: Read: Product, Store, Manager Update: Product Delete:
deleteCreditCard	Create: Read: Credit Card, Customer Update: Delete: Credit Card
registerCreditCard	Create: Credit Card Read: Customer Update: Delete:
getCNDEventDetails	Create: Read: CND Event, IT Staff Update: Delete:
solveCNDEventDetails	Create: Read: CND Event, IT Staff Update: CND Event Delete:
getDailySales	Create: Read: Store, Manager, Receipt, Product Update: Delete:
addCustomerBasket	Create: Read: Customer, Product Update: Delete:
deleteCustomerBasket	Create: Read: Customer, Product Update: Delete:
showLogs	Create: Read: IT Staff, System Log Update: Delete:
showReceipts	Create: Read: Customer, Receipt Update: Delete:

showOutdatedProducts	Create:
	Read: Store Worker, Store, Product
	Update:
	Delete:
triggerPayment	Create: Receipt
	Read: Credit Card, Customer
	Update:
	Delete:

<div align="center">Table 22: CRUD Operations</div>

Design Rationale:

- MySQL is chosen as a relational DBMS because it is an open source database management system.

- All accounting information like hashed passwords of system users are kept in Amazon Database Services, and Amazon responsible for authentication of users. Therefore, each authentication and authorization related information are kept in there.

- Since all managers, store workers and IT staff are workers, the system uses generalization in their representations. The same goes for sensor and camera.

- Credit Card is a weak entity because no credit card exists without a customer. The same goes for hardware, receipt and credit card.

- Product is in an aggregation relation with both Receipt and Store. The same goes for manager and store worker.

4.4   Interface View

In this part of view, the internal and external interfaces of the system are explained. This explanation is strengthened by sequence diagrams.

4.4.1   Internal Interfaces

The interface between Web Server Handler and Product Recognition Handler: In the cashier-less concept, all products must be identified. To do this, web server handler use the interface of product recognition handler. With this interface, web server handler can learn which product is chosen by a specific customer and it can add this item to the basket of this customer. The given input to the Product Recognition Handler is both camera and sensor data.
Design Rationale:

- Because of the modularity Product Recognition Handler should be seperate.

- Most of the time only camera data is not enough for determining a product. Therefore, the camera data should be supported by sensor data.

The interface between Web Server Handler and Customer Recognition Handler: In the cashier-less concept, all customers should be tracked. To do this, web server handler use the interface of customer recognition handler. The information of a customer detected at the entrance to the store is

cached by customer recognition handler, and his/her location is updated by this component. So, whenever web server handler wants to identify a customer, it gives the camera data and takes the customer ID in return.

Design Rationale:

- Because of the modularity Customer Recognition Handler should be separate.

- Since each customer is tracked by Customer Recognition Handler continuously, only camera data will be enough.

The interface between Automatic Payment Handler and Customer Recognition Handler: Whenever a customer exits the store, he/she is identified by Customer Recognition Handler. Since when exiting the store customer shall pay what he/she takes, Customer Recognition Handler triggers the Automatic Payment Handler, and it handles the payment of specified customer.

Design Rationale:

- Automatic Payment requires a lot of steps, for instance it shall get the credit card information of that customer. Therefore, after it is triggered, it takes the required customer data from database. As a result, it eases the payment step.

The interface between Inventory Management System and Web Server Handler: Inventory Management System is related to store operations. All requests coming from either store worker or manager are mostly related about the inventory of store. Therefore, Web Server Handler needs to interact with Inventory Management System. Also it holds the system logs.

Design Rationale:

- Inventory Management system relates each product with a store.

- Since all products and all stores are huge, they have to be organized and handled by different component.

- After the authorization of worker, almost each worker operation is done thanks to interface between Web Server Handler and Inventory Management System.
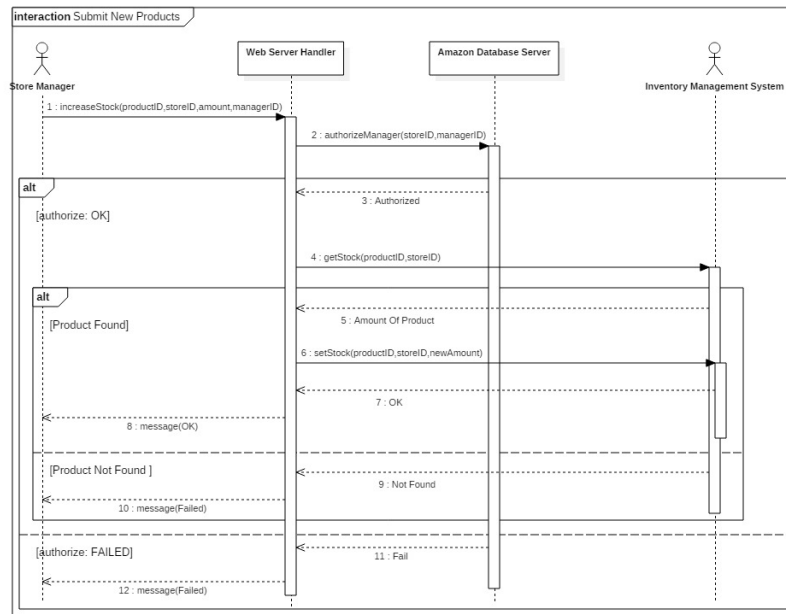
Figure 7: Submit New Products sequence diagram showing the interfaces between Inventory Management System and Web Server Handler

The interface between Web Server Handler and Camera and Sensor Management System:
Each store has a lot of cameras and sensors, and Camera and Sensor Management System deals with the configuration and data operations of them. All data and configuration of these devices are done using this interface

Design Rationale:

- Camera and Sensor Management System is fully a commercial off-the-shelf (COTS) system. Therefore, its operation shall be done through an interface.
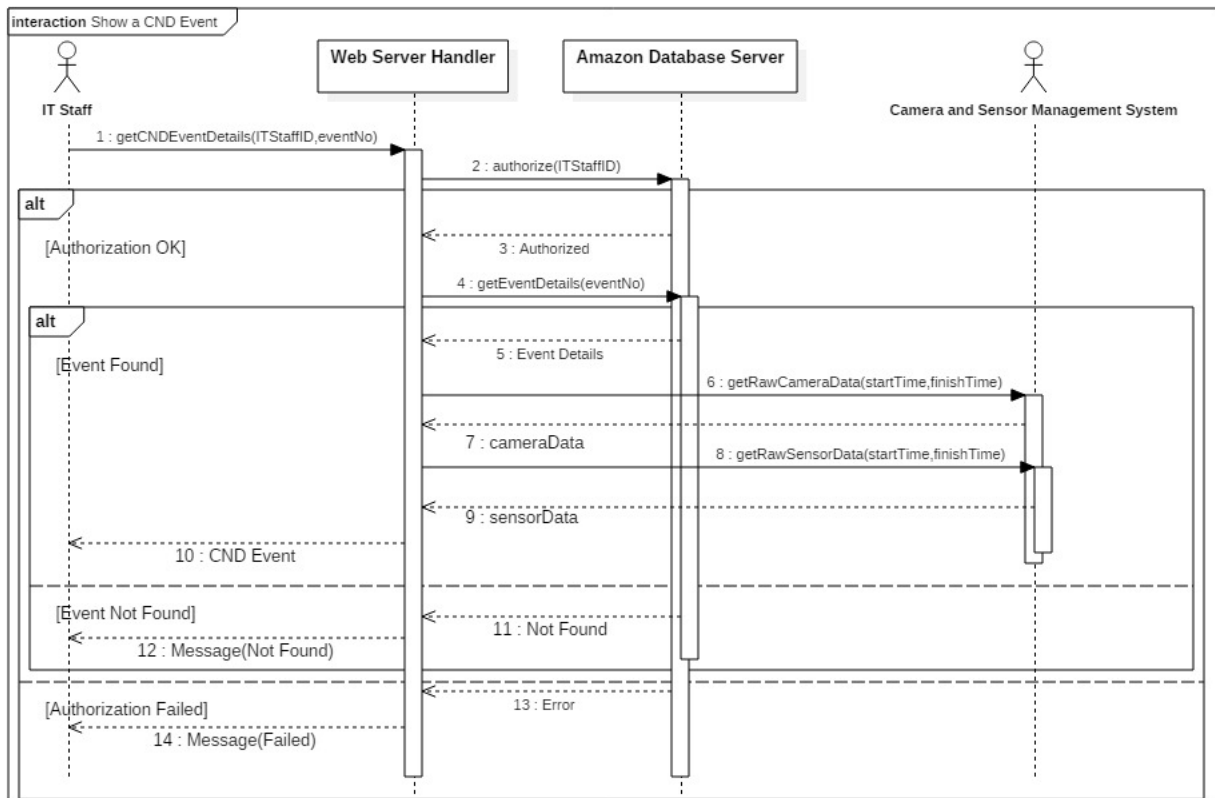
Figure 8: Show CND Events sequence diagram showing the interfaces between Camera and Management System and Web Server Handler

4.4.2 External Interfaces

4.4.2.1 User Interfaces

User interfaces are accessed through two different systems. The first one is the Amazon Go mobile application and the other one is a website. Store workers, IT Staff, customers, and managers use the website to access the system. Also, customers use their mobile applications during shopping to access the system.

Store Worker Interface: System provides an interface for store workers. They access this interface through a website. This interface should be easy to use. Most of the functionality is done by using this interface. It has two main tabs, the one is related to products, the other one is a form that allows creating a temporary account.

In the first tab, a store worker can see the status of his/her store. Mainly it can see outdated products. Also, the notification of empty shelves is shown in this tab.

In the second tab, a store worker can create temporary accounts, and this feature is located in this tab. Whenever a customer comes to the store, and he/she wants to do shopping, if he/she doesn't have an Amazon account, a temporary account should be created for him/her. This is done by store workers, and they simply fill the information form that is located in this tab to achieve temporary account creation.

Design Rationale:

- Design of interface is simple, so any worker can use this interface easily.

- The main duties of workers are simply gathered in two tabs.

- To ease the identification process of products for store workers, the picture of some products is shown in the interface.

Manager Interface: Store manager interface has similar capabilities like store worker interface but has more additional features. They access this interface through a website. Managers can interact with other components of the system, therefore the interface should provide an abstraction to them. There are mainly three tabs in the system. They are used for accessing Amazon DB Service, Inventory Management System, and Camera and Sensor Management System.

In the first tab, a store manager can do operations related to Amazon DB Service such as showing daily sales. These kinds of related database operations shall be simplified because managers don't have to know SQL queries. To achieve this, there are some prepared search bars in this tab.

In the second tab, store managers' operations on products are defined. Again, these operations require interaction with the Inventory Management System, therefore there are a lot of small forms in this tab to ease the interaction. For instance, if a manager wants to submit a new product, it can fill an increase in the stock of a product form.

In the third tab, store managers can interact with the devices in their stores. Therefore, they configure and show the status of devices using this interface. Again, this interface is simply the same as before.

Design Rationale:

- Managers can switch the tabs by clicking one of the three buttons which are "Device Operations", "Database Operations", "Inventory Operations".

- Most use cases are done by simply filling the corresponding mini form.

- Helps and descriptions of each operation are summarized above each mini form.

IT Staff Interface: IT Staff interface is used for checking logs and errors. IT Staff are technical people, therefore their interface is more complicated than store workers' and managers'. They can see the logs for a specified time, and they can see and solve the CND Events. Because of this reason, there are two tabs in the interface.

In the first tab, IT Staff deal with system logs. They can see the whole logs, or they can select system logs that occur at a specific time. Since the system usually has a lot of log records, this tab cannot fit one size.

In the second tab, IT Staff handles the CND events. In this tab, there are CND event details that occurred in the system. They can reach the specific sensor and camera data related to a specific CND Event. Also, they can solve a CND event using this tab.

Design Rationale:

- Since in the log operations, there may a lot of logs, there is a Return To Start Button to return the beginning of logs.

- Interface shall be able to filter or sort the coming logs.

- While observing the details of a CND event, the interface gives both data synchronously. This means that video records for a particular moment are supported by sensor data.

Customer Mobile Application Interface: This interface is the main interface for customers. It is accessible through a mobile application that is installed on Android or Apple smartphones. It is a comprehensive interface that provides a lot of use cases to customers. Main features are entering the store, showing past receipts, looking at the nearest store locations, checking personal information, and registering a credit card. Throughout their shopping, their baskets are shown in this interface so that they can check the total cost of products that they take. It has a lot of tabs to split this feature more logically.

Design Rationale:

1. It includes a comprehensive introduction about the usage of the Amazon Go stores

2. Since it is for customers, aesthetic details are very important, and it is designed with considering this goal.

3. Users can see their baskets after entering the store, and the basket information is regularly updated. by the interface.
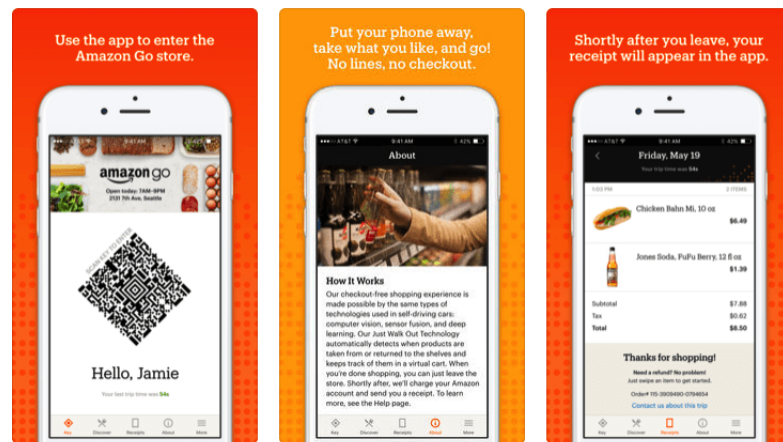

Figure 9: Screens from Customer Mobile Application Interface

Customer Website Interface: This interface is another interface for customers. It is accessible through a website. In this interface, there are not many operations related to use cases. It is simply for checking personal information. Users can learn the system using this interface because there is an introduction that tells people how to use Amazon Go.

Design Rationale:

1. Aesthetic details are also important for this interface. So, it is responsive to different mobile phones, or computers to preserve the aesthetic.

2. Also using this interface, customers can update or change their personal data.

4.4.2.2 System Interfaces

The Interface Between Web Server Handler and Google Maps: Web Server Handler handles the requests coming from customers. This interface is mainly used for location operations. After it receives a request for showing store locations from a customer, it uses an API Key to authorize the system in Google Maps. If it gets the authorization, it receives the list of coordinates of stores and a world map from Google Maps and show the map to the customer with information including locations of all stores and nearest stores.

Design Rationale:

- If the authorization is not completed, process cannot be completed.

- The internet connection is a must for each part of the process. If the internet connection between customer and Web Server Handler or Web Server Handler and Google Maps is down, the connection error message is sent to the customer by the Web Server Handler.

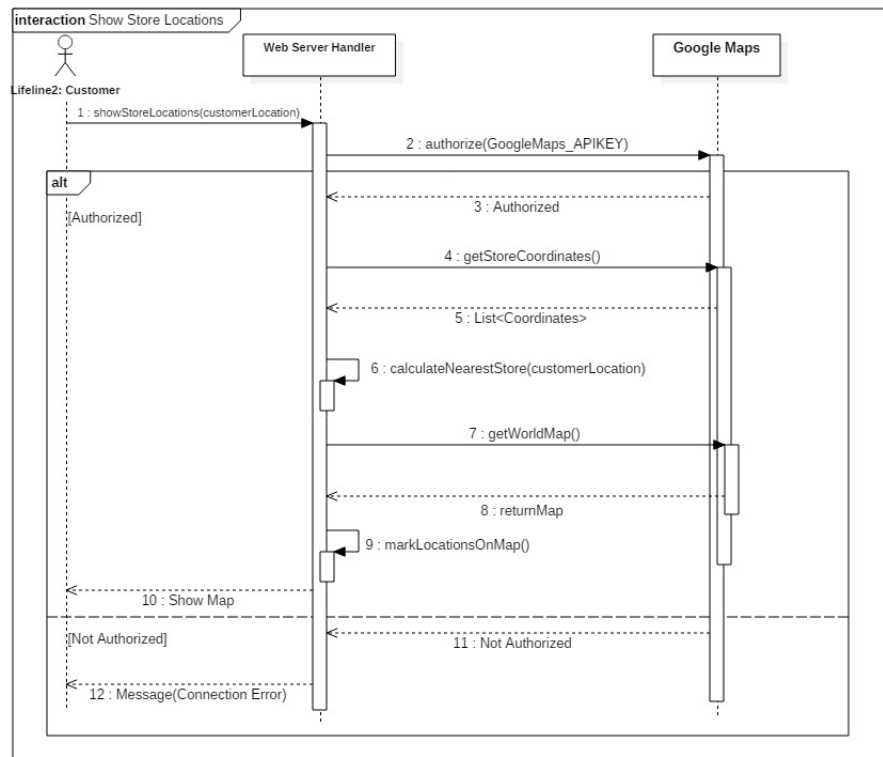- The store locations on the map are not saved in the customer application.

Figure 10: Show Store Locations sequence diagram showing the interfaces between Web Server Handler and external system Google Maps

The Interface Between Web Server Handler and Amazon Database Server: Amazon Database Server is responsible for storing information about customers, workers, stores, CND events, system logs, etc. Since nearly all information that is needed for operations, Web Server Handler shall interact with Amazon Database Server through an interface. Through this interface, Web Server Handler can execute

database queries.
Design Rationale:

- Information in Amazon Database Server is protected and permissions vary user by user. Any request for accessing any forbidden information ends with "permission denied" error.

- Web Server Handler can execute SQL queries through methods that are provided by the interface.

The Interface Between Automatic Payment Handler and Amazon Database Server: When a customer exits the store, payment of his/her shopping is supplied by Automatic Payment Handler. While this process is happening, there is some information required such as customer identities and his/her credit card information, and these are only received by Amazon Database Server. Therefore, Automatic Payment Handler needs to execute SQL queries on Amazon Database Server to provide payment.
Design Rationale:

- Like the interface between Web Server Handler and Amazon Database Server, the interface provides SQL query executions.

- Most of the time, it gets the credit card information from Amazon Database Server.

The Interface Between Automatic Payment Handler and Virtual Payment Pos: After a customer exits the store, the Automatic Payment Handler is triggered and connects Virtual Payment Pos in the payment part of the process. Automatic Payment Handler collects required credit card information and sends them to Virtual Payment Pos with a payment request. After the payment operation, it saves receipts of the customer in Amazon Database Server and returns with situations that payment done and then customer exits.
Design Rationale:

- This interface provides a Virtual Pos to the system.

- Since all the operations that are made through this interface are critical, all communication between these two components is encrypted.
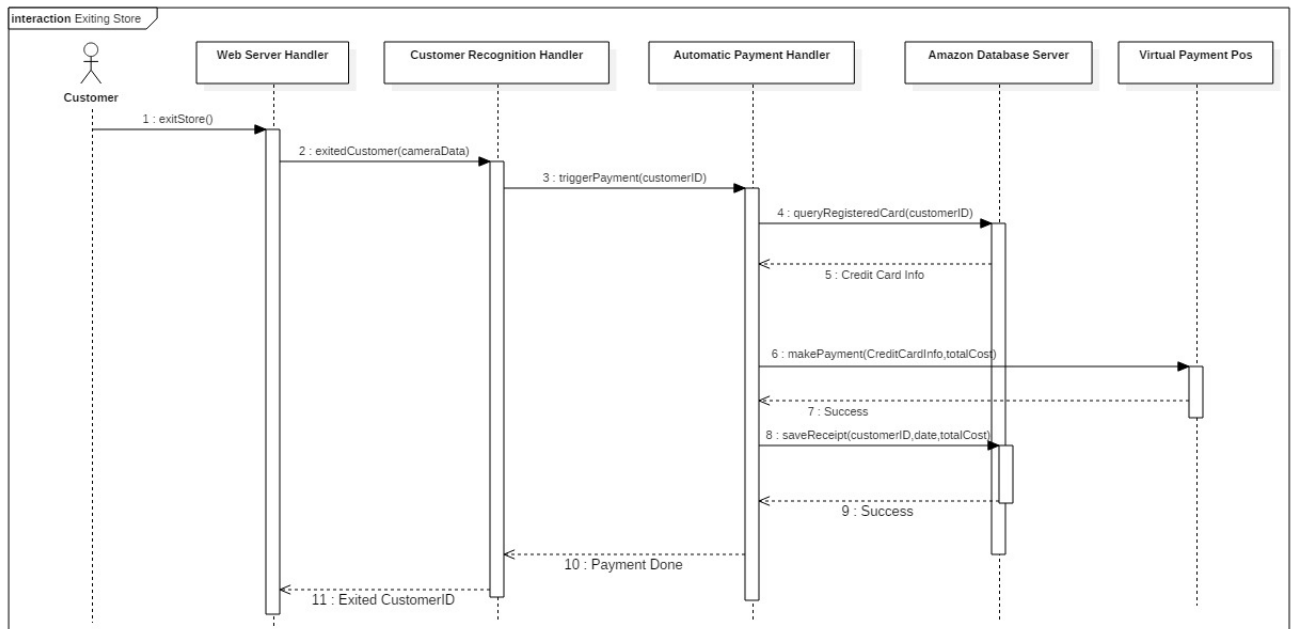
Figure 11: Exiting Store sequence diagram showing the interfaces between Automatic Payment Handler and external system Virtual Payment Pos

The Interface Between Web Server Handler and Virtual Payment Pos: Since Virtual Payment Pos wants credit card information of the customer for automatic payment, this is provided by Web Server Handler. Before the shopping, customer's credit card information is registered to the system and saved in Amazon DB Service. If saving is successful, "Card is saved." message returns to the customer from Web Server Handler. During the registration process, 1 dollar is withdrawn from the credit card by Virtual Payment Pos, and then it is refunded so that it can be understood whether received credit card information is valid or not.

Design Rationale:

- If saving credit card information to Amazon DB Service fails, an error message is sent to the customer by Web Server Handler.

- All credit card information of customers is protected in Amazon DB Service and the access is restricted to them.
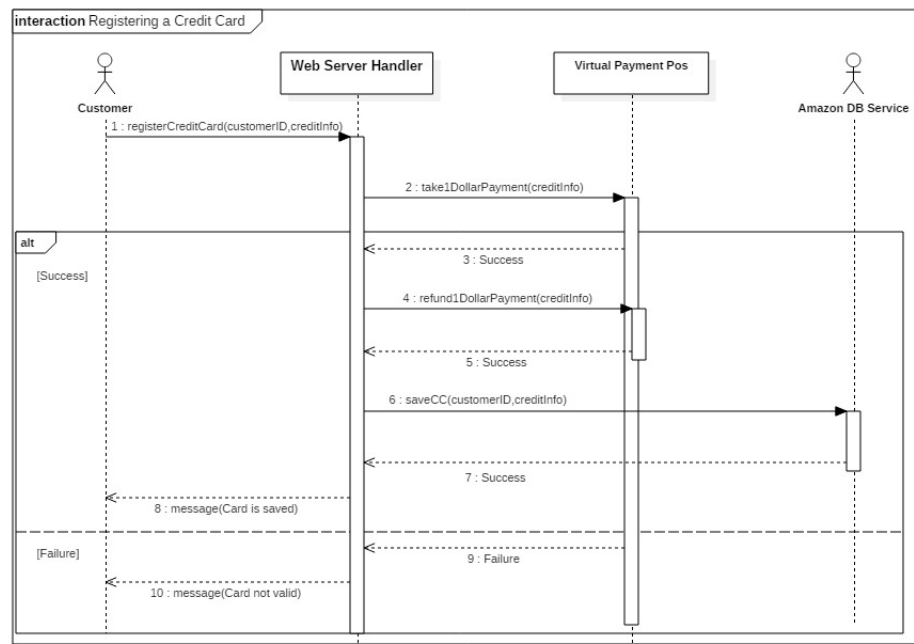
Figure 12: Registering a credit Card sequence diagram showing the interfaces between Web Server Handler and external system Virtual Payment Pos