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**ASIA PACIFIC UNIVERSITY
OF TECHNOLOGY & INNOVATION**

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1.0 Introduction

A touchless car wash is a highly advanced, fully automated system designed to clean cars with high-pressure water and cleaning solutions without any type of direct contact. A system like this has been developed to avoid scratches or any other potential damage from brushes, catering to much safer options for cars when compared to a normal car wash. The process, which mainly includes washing, pre-soaking, rinsing, and sometimes the application of wax or drying by the use of jets and spray arms to reach all areas of a stationary vehicle. (Mary, 2023)

Our company is developing a touchless car wash controller to respond to the demand for safer, more efficient automated car wash. The system cleans cars with the help of powerful cleaning agents and high-pressure jet sprays to minimize scratches and damage. Designed on LabVIEW, the controller will operate all wash stages from the underbody cleaning right to soap application, rinsing, and air drying depending on the chosen option. Proximity sensors provide accurate positioning of the vehicle, while safety features like emergency stop buttons and alignment warnings add to the reliability of the system. This controller is developed to make the touchless car wash process easier and safer with clear display and indicator lights for the users as well.

Advantages of a Touchless Car Wash

1) Reduce Risk of Paint Damage

- Since, brushes or sponges are not utilized, the potential for paint damage on the car is greatly minimized. Too add on, vehicles that is washed with a brush occasionally would get swirl marks or even scratches if the brushes were not kept in a good condition. (Sullivan, 2021)

2) More Efficient

- Touchless car washes generally take less time compared to the traditional car washes using brushes. The entire process of washing can be done in less than a few minutes. This speed is essentially helpful for those people that have tight schedules or those that need a quick wash without wasting too much time.

3) Environmentally Friendly

- Compared to traditional car washes, touchless systems generally use less water because they rely on high-pressure water jets, which uses less overall volume compared to traditional washes. Many touchless systems also utilize biodegradable soaps making them more attractive for people that are more eco-conscious. (Sullivan, 2021)

Disadvantages of a Touchless Car Wash

1) Higher Cost

- While generally faster and less labour-intensive touchless car washes sometimes may be more costly than a traditional car wash at times, especially when premium services or advanced features are added. For people with a tight budget, this might add up if frequently used. (Detailing, N.A.)

2) Water Spotting

- Touch-free washes and traditional car washes alike, if not dried properly it may leave water spots. These can be most unsightly on a darker-coloured vehicle and often require going over the vehicle again with a microfiber cloth for a spot-free finish. (Detailing, N.A.)

3) Limited Cleaning Power

- Touchless car wash struggles to take off stubborn dirt, grime, or bug splatters due to the lack of physical brushing. This might be problematic in cases of heavy dirt buildups on a vehicle, where another round of cleaning or extra manual touching up is needed for a clean finish. (Detailing, N.A.)

2.0 Assumption

1) Customer Familiarity with System Operations

- Assume the customers understand generally how an automated car wash works. The system should guide a customer in the most simplified way to avoid confusion or misuse that would lead to delays during the process.

2) Power Supply Reliability

- It's assumed that the car wash has a constant uninterruptible power supply, so its wash cycles are not disrupted due to changes in power supply. Power surges and fluctuations should be taken care of through a backup power system so that its wash cycle would not get interrupted at any moment during the wash.

3) Weather Resilience

- Car wash equipment and electric components are well-built to tolerate all sorts of unexpected weather to ensure adequate function in heavy rain or even thunderstorms.

4) Vehicle Standard Dimensions

- The car wash is assumed to be able to handle the standard dimension of vehicles and not ones with special attachments which might require manual assistance.

5) System Reboot after Each Use

- The system should automatically reset itself for each subsequent use at the end of the car wash cycle without requiring human intervention.

7) Safety Compliance Standards

- All equipment and procedures are assumed to follow local health and safety compliance. This includes easy access to emergency stops, waterproofing of electrical components, and clear indicator signage.

8) Self-Correcting Mechanisms for Misalignment

- The system is assumed to include guides for proper alignment that can properly accommodate minor misalignments, reducing the risk of damage.

3.0 System Design

3.1 Storyboard

Scene 1: User Login and Registration

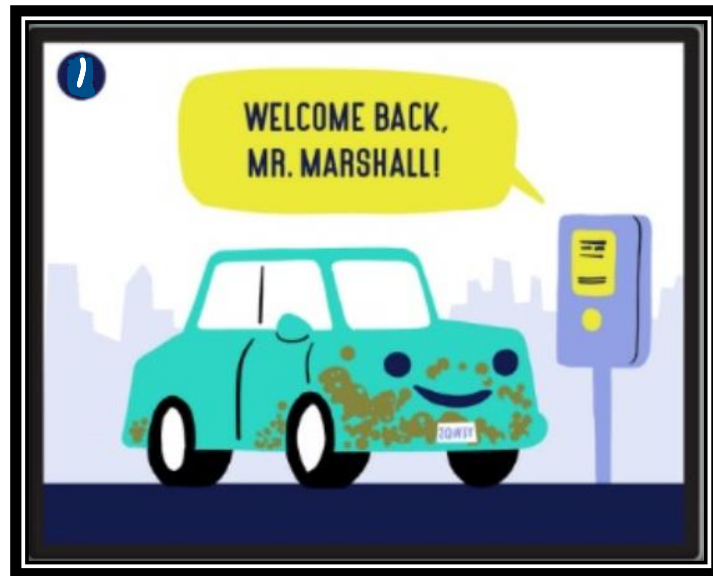


Figure 1 Customer Login or Register

First, the customer logs in on the screen by putting in their username and password; if the customer does not have an account, they can quickly sign up before they choose their wash option.

Scene 2: Choose Wash Option

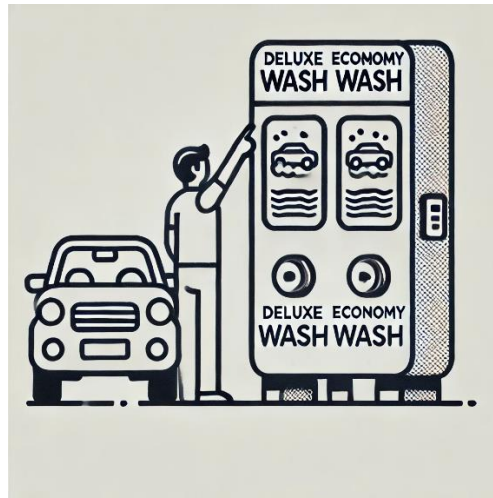


Figure 2 Choosing Car Wash Type

Based on the display, the customer presses a button to choose between either the Deluxe or Economy wash option; one will give them more service than the other.

Scene 3: Underbody Wash (Deluxe Option ONLY)



Figure 3 Underbody Wash

The customer drives through slowly, stopping in position until the underbody wash section is reached. As a customer aligns his vehicle, an active sensor detects where his car is to confirm that it has reached the proper position. If one is incorrectly positioned, an LED light is used to indicate misalignment, and the process only starts working if the vehicle is correctly positioned. When the underbody wash is done a red light will be shown to tell the customer to move on.

Scene 3: Soaping



Figure 4 Soap Application

Next, the customer drives forward slowly, enters the main wash area, and positions his vehicle above the alignment humps. A sensor detects whether the vehicle is properly aligned and gives an LED signal that confirms everything is set. Then, it starts soaping.

Scene 4 High Pressured Wash

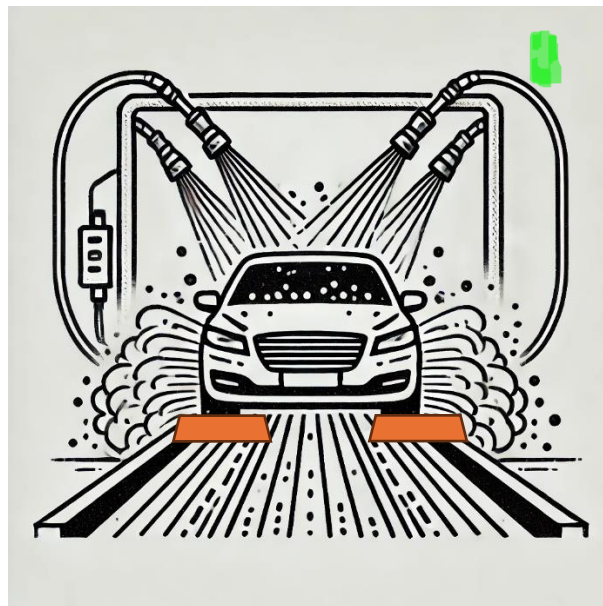


Figure 5 High-Pressure Wash

After soaping, the vehicle remains in the same position, ready for the high-pressure wash. Sensors continue to monitor the vehicle's location to maintain alignment for optimal cleaning.

An indication light acts as an additional signal to signify whether the vehicle is in the correct position and only then will the high-pressure jets begin to take off the soap efficiently.

Scene 5 Clear Water Rinse



Figure 6 Clear Water Rinse

After the high-pressure wash, the vehicle remains in the same position for the Clear Water Rinse cycle. Sensors ensure the correct positioning of the vehicle, while an indicator light

initiates this clear water rinse phase. At the end of the rinse cycle, the system triggers the "Vehicle Out of Position" light to have the driver proceed to the next car wash station.

Scene 6 Air Dry

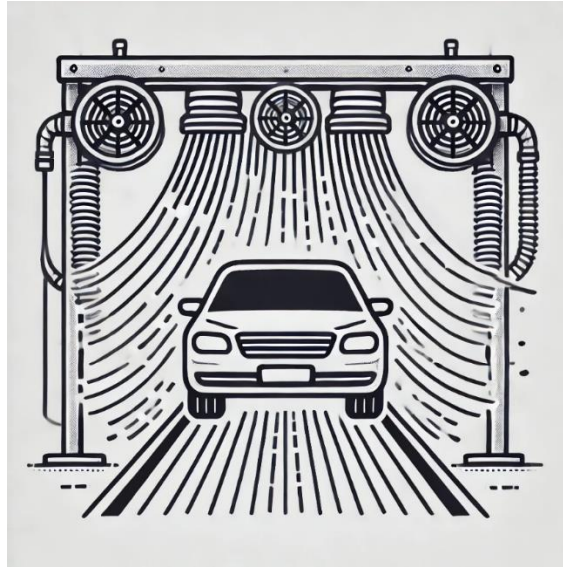


Figure 7 Air Dry

After passing through the clear water rinse, the vehicle proceeds to the Air Drying Cycle. The sensors at the drying area will detect the position of the car as it enters and align for drying. There is an indicator light that then turns on once it is in position, initiating the air drying

process for 10 seconds. Once the cycle is complete, the "Vehicle Out of Position" light turns on, signalling the driver to exit the car wash and completing the process.

Scene 7 Wash Completion



Figure 8 Finished Wash

A final "Thank You" message appears at the end of the car wash as the vehicle exits. It is a nice, friendly acknowledgement that indeed the car wash is completed.

3.2 Use Case Diagram

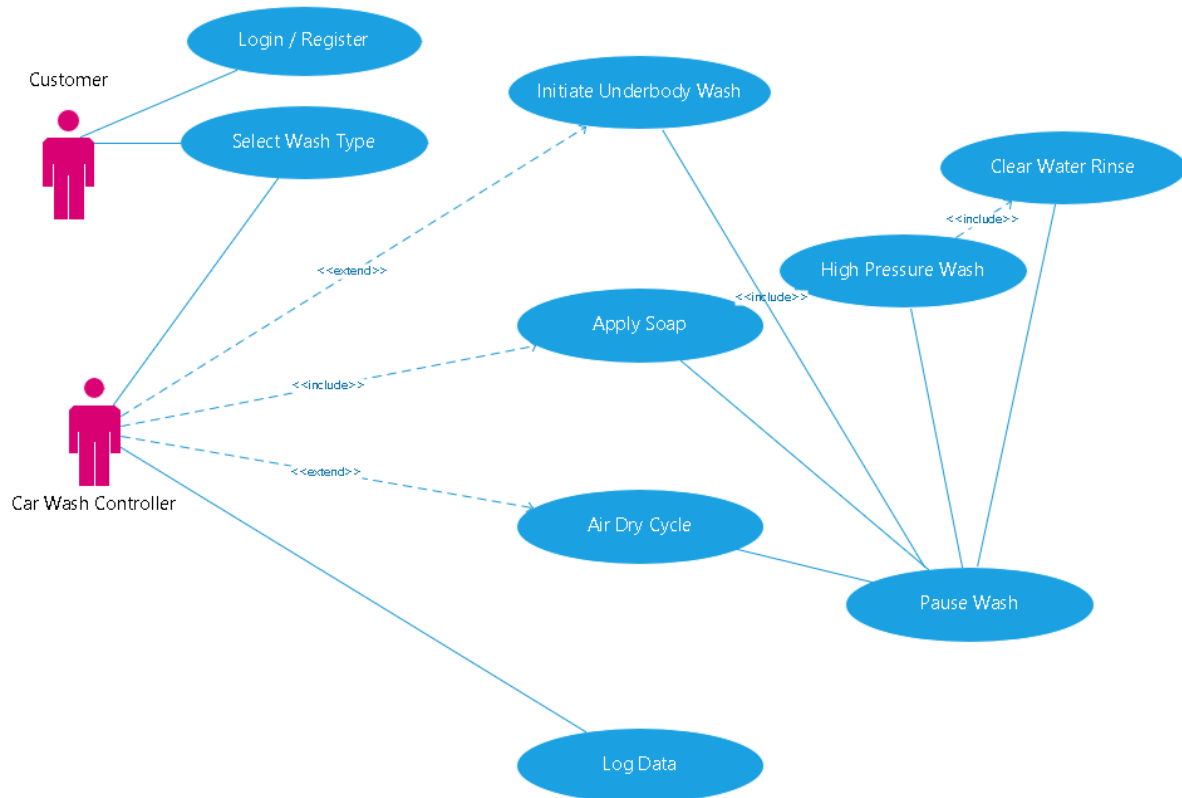


Figure 9 Customer Use Case Diagram

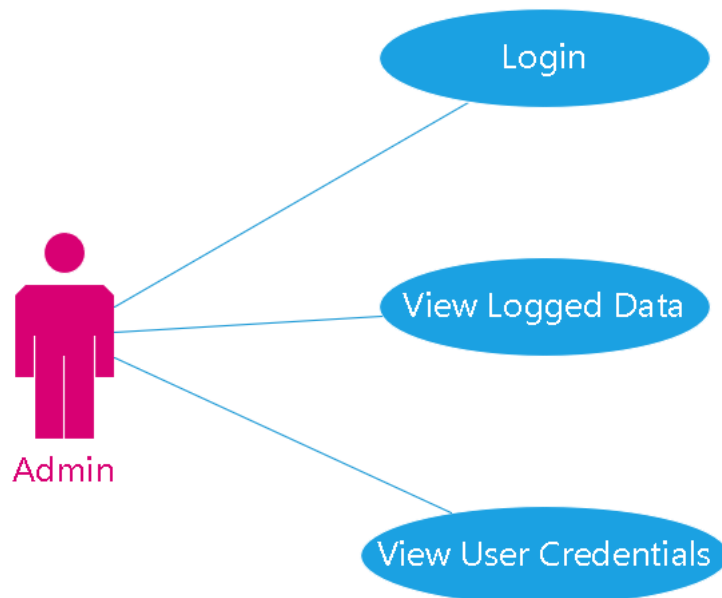


Figure 10 Admin Use Case Diagram

3.3 Use Case Description

Use Case	Login and Registration
Brief Description	This use case allows a user to either create a new account or log in to his previously created account.
Actors	Customers
Preconditions	1) The customer goes to the car wash display panel and is presented with the opportunity to log in or register. 2) For new registration, the customer does not have a pre-created account with the system. 3) For login, the customer is registered and the system database is accessible for verification of entered credentials.
Postconditions	User becomes authenticated and access to the system is gained.
Trigger	User selects "Login" or "Register".

Use Case	Select Wash Type
Brief Description	This use case represents the customer choosing a wash type.
Actors	Customer
Preconditions	1)The car wash system is reset and ready for a new wash session 2)The vehicle is positioned in front of the car wash entrance, 3)The selection panel is on for the customer to select a wash type.

Postconditions	The selected wash type is locked in and the washing process begins.
Trigger	Activated by the customer through the menu.

Use Case	Initiate Underbody Wash
Brief Description	The system performs an underbody wash as part of the Deluxe wash.
Actors	Car Wash Controller
Preconditions	1)The customer has selected the Deluxe wash 2)The vehicle is aligned over the underbody spray area, as detected by the proximity sensor Switch.
Postconditions	Underbody wash completes, or halts if the car is out of position.
Trigger	Proximity sensor detects vehicle in place.

Use Case	Apply Soap
Brief Description	Soap is applied to the vehicle. This is part of both Deluxe and Economy washes.
Actors	Car Wash Controller
Preconditions	1) Confirmation is received by the system that the underbody wash has successfully completed. 2) The Main Wash Position Switch guarantees that the vehicle is in the correct position to apply soap.
Postconditions	Soap is applied for 5 seconds or pauses if the vehicle moves.
Trigger	The second switch is triggered.

Use Case	High-Pressure Wash
Brief Description	A high-pressure wash follows after the application of soap.
Actors	Car Wash Controller
Preconditions	<p>1) The soap application cycle has been completed, which then sends a notification to the system to proceed with the high-pressure wash</p> <p>2) The vehicle is still in the correct positioning in the high-pressure wash area and confirmed by the Main Wash Position Switch.</p>
Postconditions	The high-pressure wash completes or stops when the car moves.
Trigger	Soap application is completed

Use Case	Clear Water Rinse
Brief Description	The vehicle is washed with clear water to take off remaining soaps.
Actors	Car Wash Controller
Preconditions	<p>1) The high-pressure wash cycle is complete.</p> <p>2) The vehicle remains in the rinse area signalled by the Main Wash Position Switch.</p>
Postconditions	Clear water rinse is completed or halted in case the car moves.
Trigger	High-pressure wash is complete

Use Case	Air Dry Cycle
Brief Description	The system dries the vehicle after rinse. Available only in Deluxe wash.
Actors	Car Wash Controller

Preconditions	1) The Deluxe wash option was selected 2) The final rinse cycle is complete. 3) The car has moved into the drying position. This is verified through the Air Dry proximity sensor Switch.
Postconditions	Drying is completed or it stops when the vehicle moves.
Trigger	The proximity sensor detects the vehicle position after rinsing.

Use Case	Log Data
Brief Description	The system logs information about the car wash session that has just been completed.
Actors	Car Wash Controller
Preconditions	1) The entire wash process has been completed
Postconditions	All details like the type of wash, date, time, and duration of each cycle are logged.
Trigger	The completion of the whole wash process.

Use Case	Login (Admin)
Brief Description	This use case allows the admin to log in into the system with their credentials for verification purposes.
Actors	Admin
Preconditions	1) The admin is on the server system login interface 2) The admin already has an account in the system which are stored in the text file
Postconditions	1) The admin gets authenticated and successfully logged into the system

	2) Admin gets access to the various system functionalities which includes view logged data, and user credentials
Trigger	The admin selects the "Login" option and inputs his or her username and password
Use Case	View Logged Data
Brief Description	This use case allows the admin to view data logs created from the car wash system,
Actors	Admin
Preconditions	1) The admin has logged into the system.
Postconditions	1) The admin successfully views the logged data on the system interface.
Trigger	Admin chooses the "View Logged Data" option from the admin panel.

Use Case	View User Credentials
Brief Description	This use case allows the admin to view the credentials of the different users who have registered
Actors	Admin
Preconditions	1) The admin has logged into the system.
Postconditions	1) Admin successfully views the List of user credentials.
Trigger	Admin chooses the "View User Credentials" option from the admin panel.

3.4 Activity Diagrams

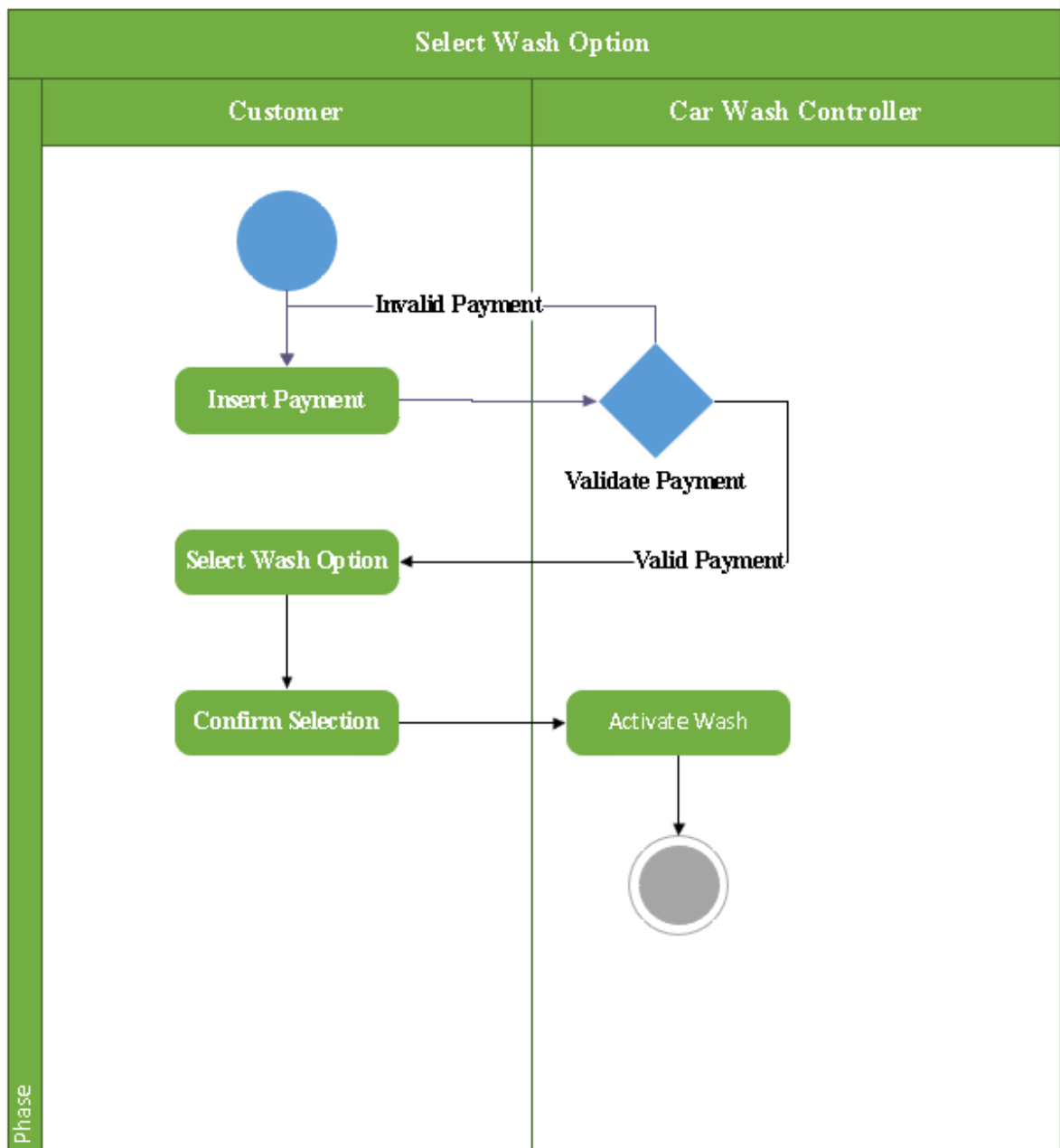


Figure 11 Select Wash Option Activity Diagram

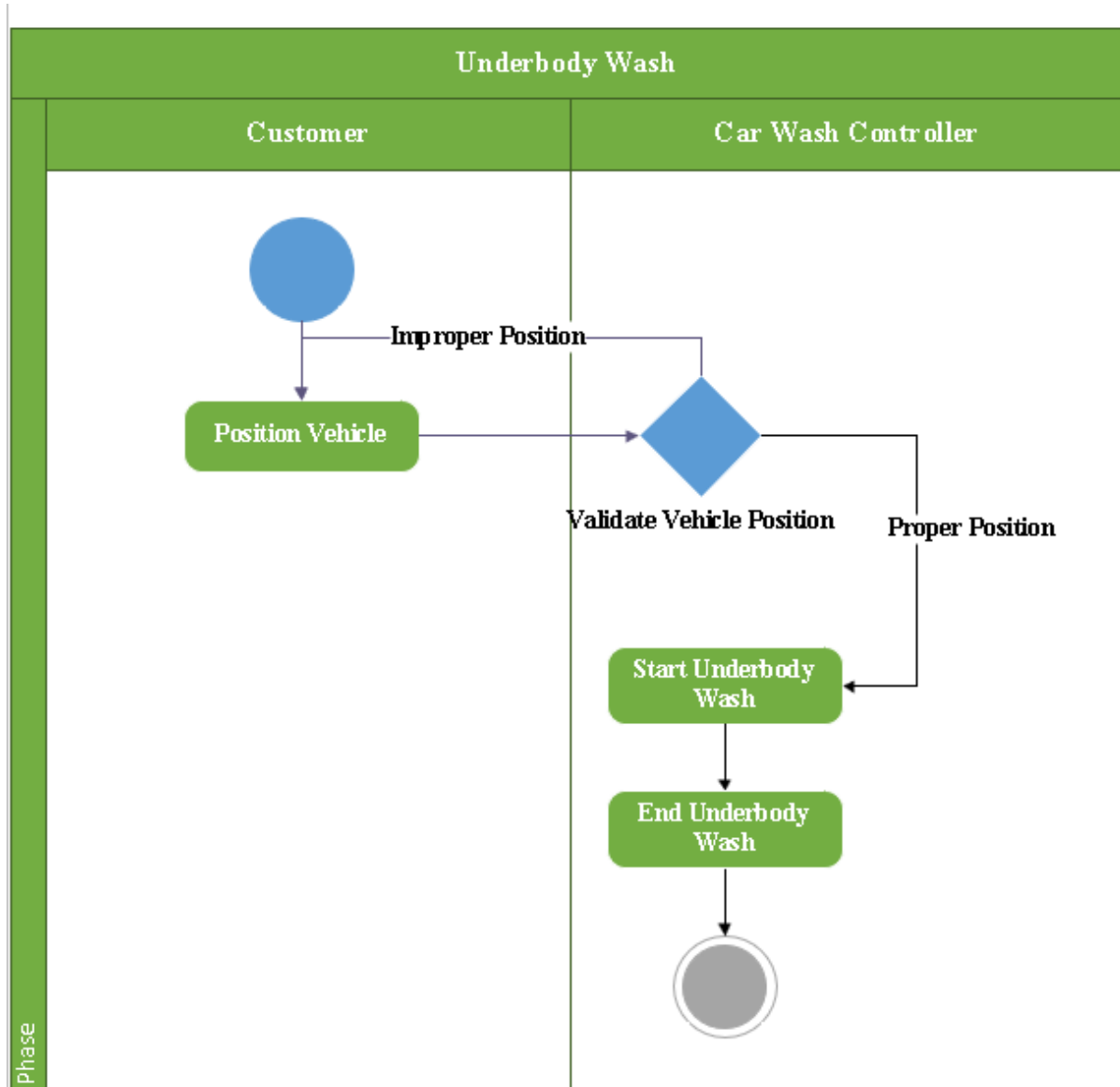


Figure 12 Underbody Wash Activity Diagram

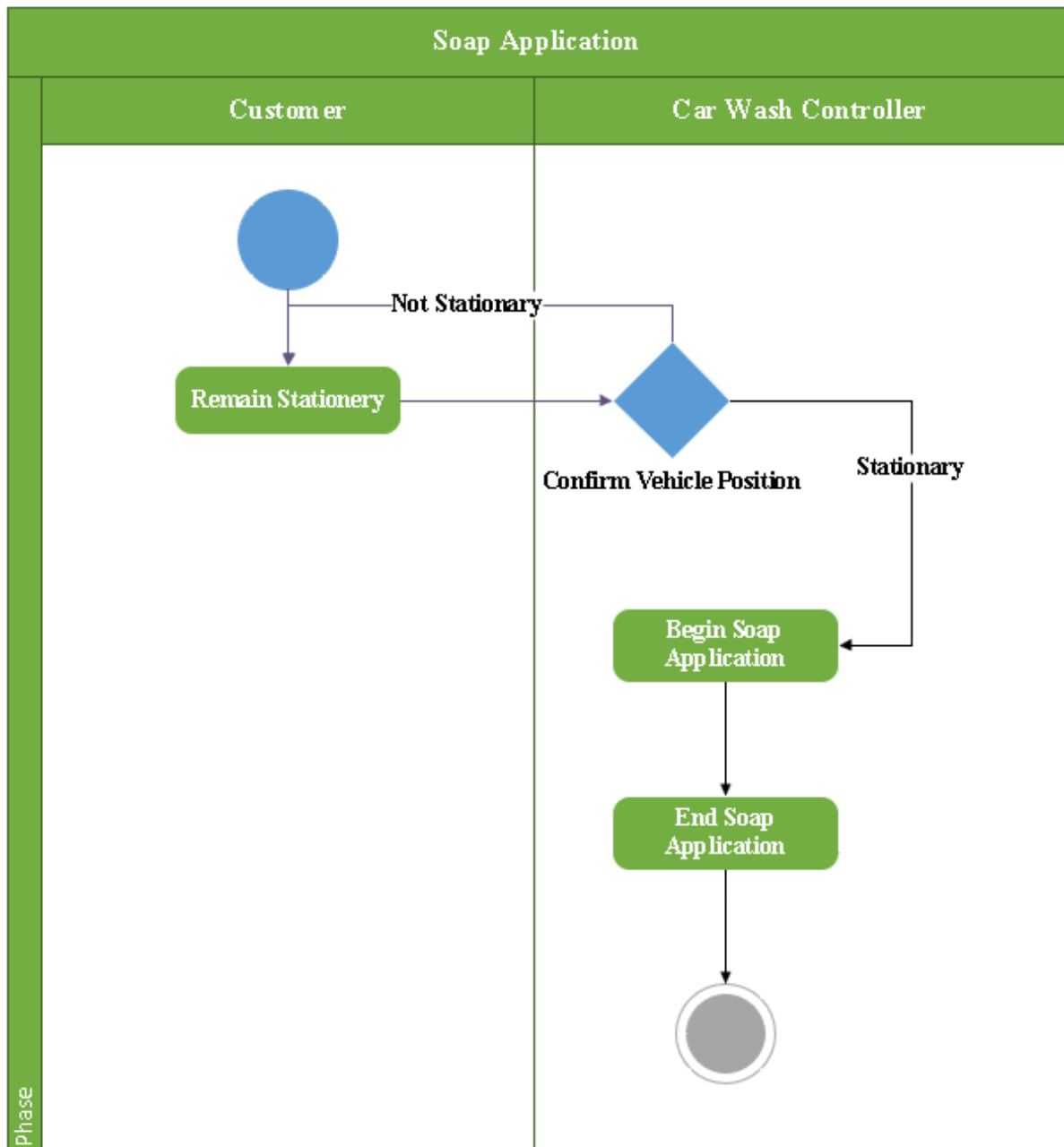


Figure 13 Soap Application Activity Diagram

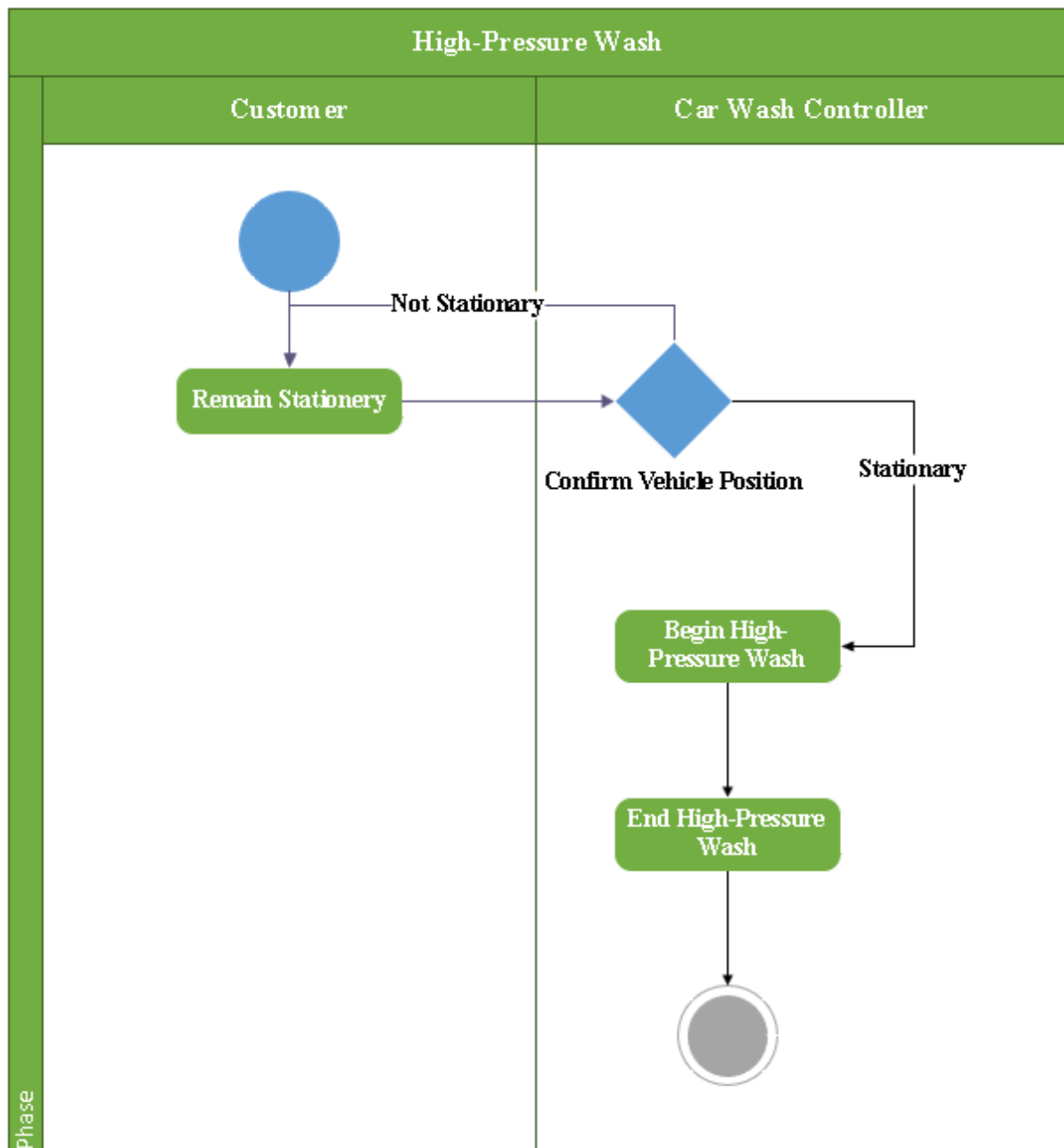


Figure 14 High-Pressure Wash Activity Diagram

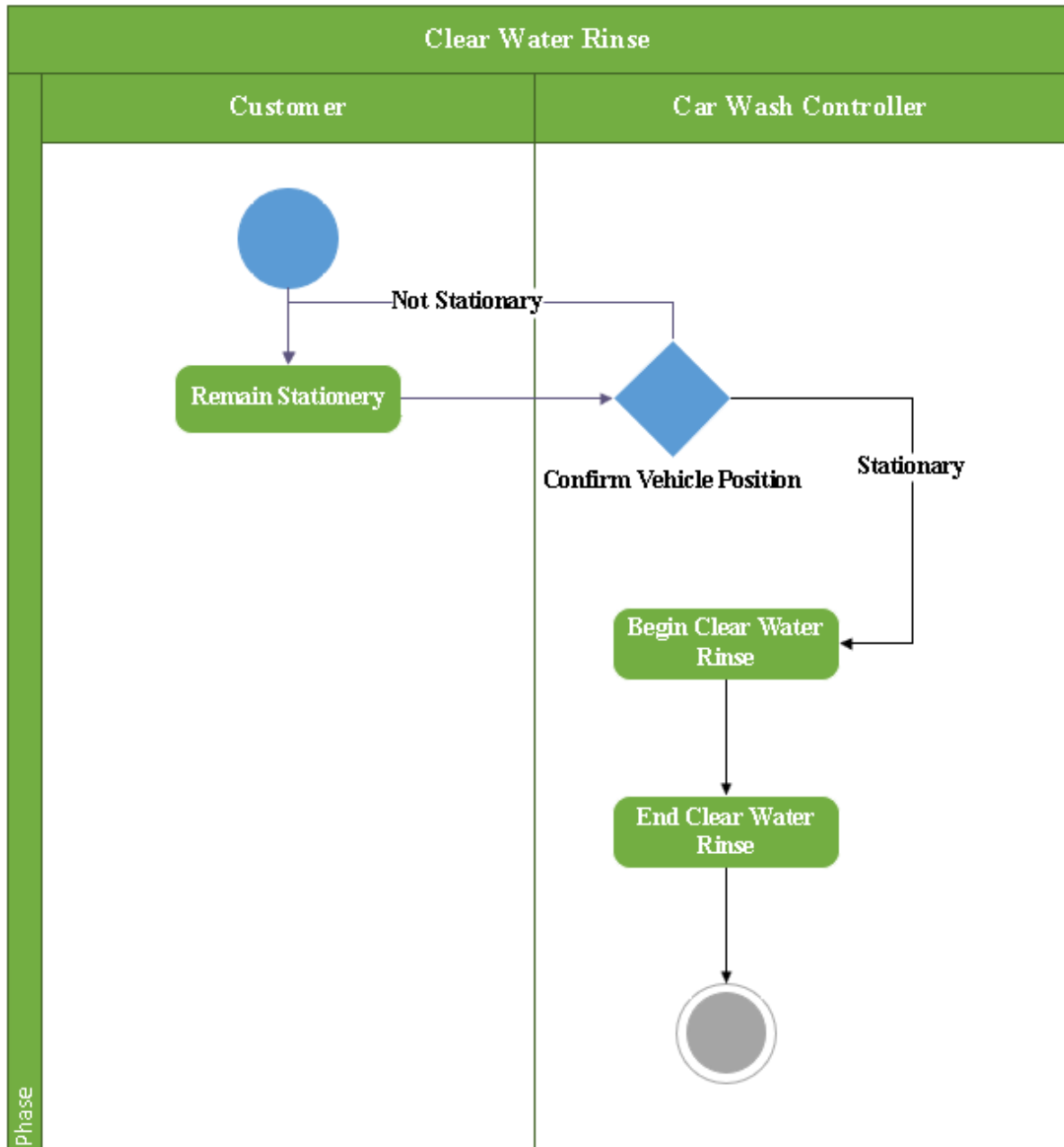


Figure 15 Clear Water Rinse Activity Diagram

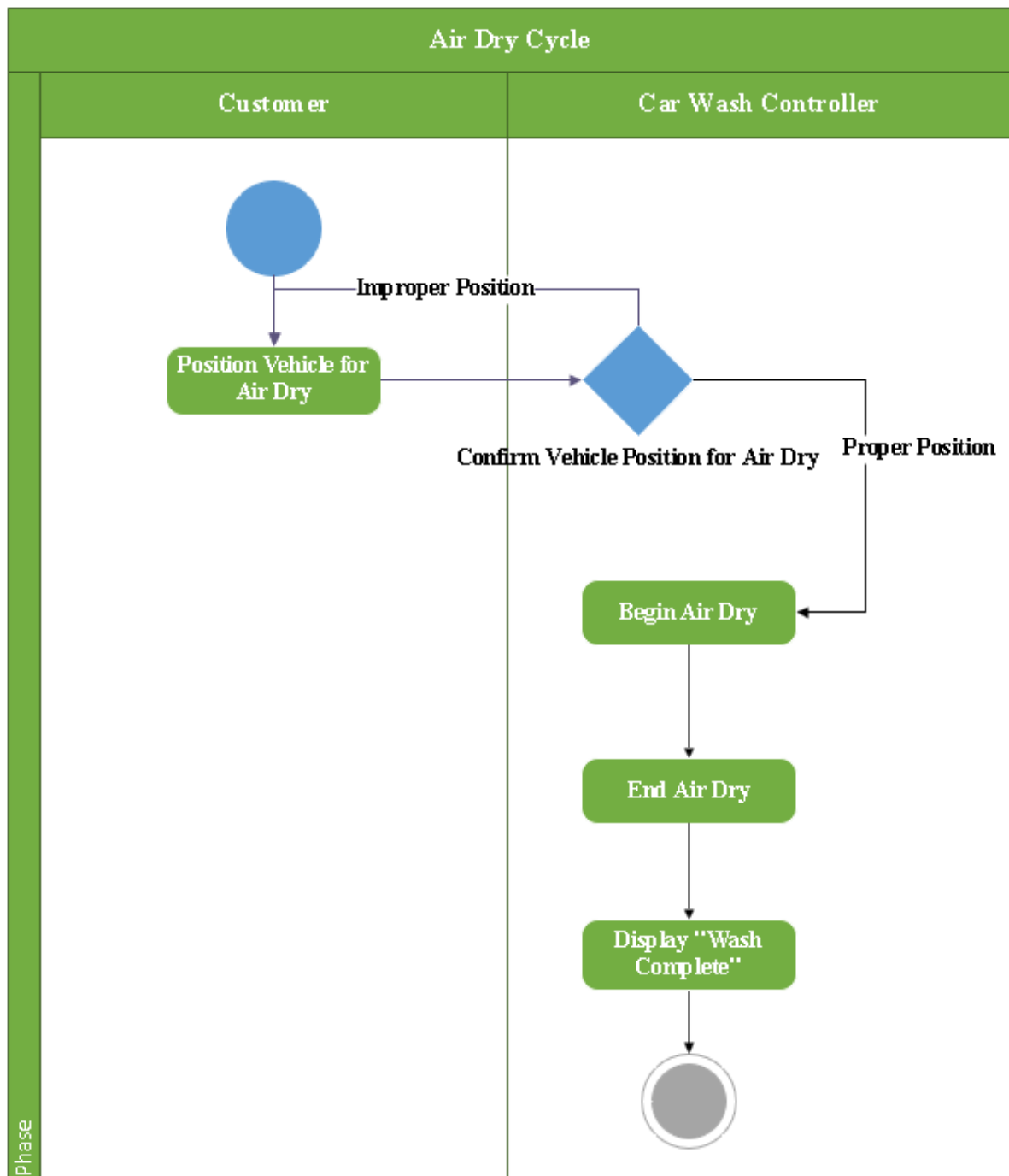


Figure 16 Air Dry Activity Diagram

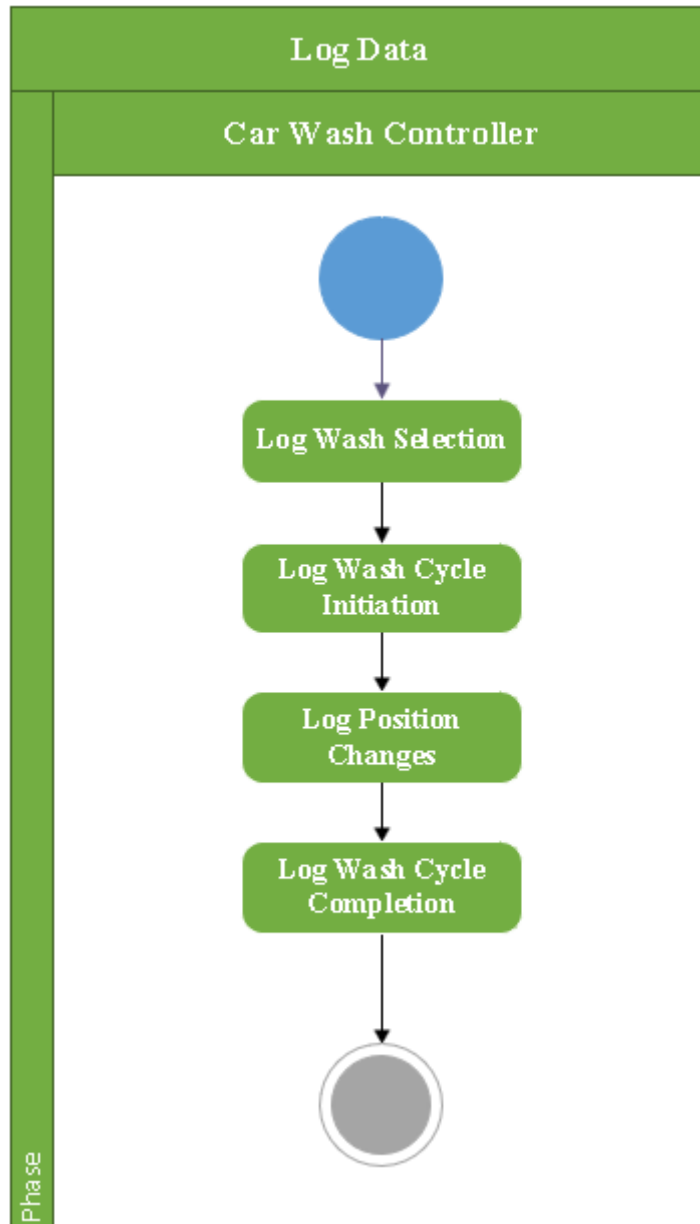


Figure 17 Log Data Activity Diagram

3.5 State Diagrams

Client Side

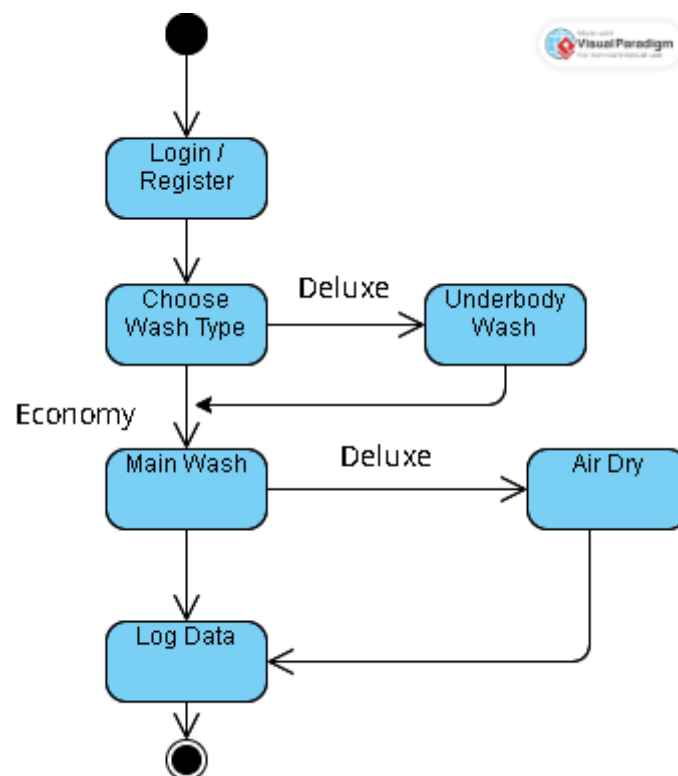


Figure 18 Client State Diagram

Server Side

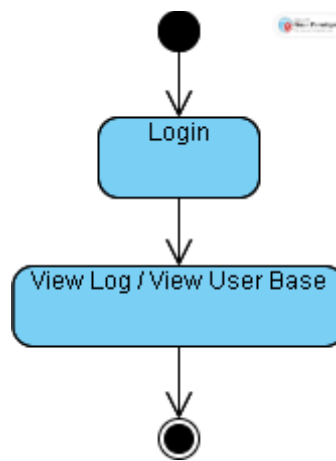


Figure 19 Server State Diagram

4.0 Protocol Design

4.1 Client Protocol Design

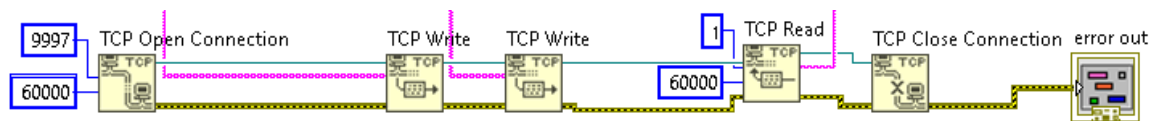


Figure 20 Client TCP/IP

The client-side program begins by concatenating the entered username and password into a single string to be sent. It then determines the length of the string using String Length, converts it to numeric format using Number to Decimal String and connects to the server at port 9997 using TCP Open Connection with a 60-second timeout. The credentials and length are sent to the server sequentially in two successive steps via TCP Write; this ensures that the information is transmitted correctly. To add on, the client waits for the response of the server with TCP Read with a timeout of 60 seconds, to determine if this was a successful login or not. Once the response is received, the TCP Close Connection closes the connection and handles any errors during the process through the error out. This ensures a secure and reliable communication between the client and the server.

4.2 Server Protocol Design

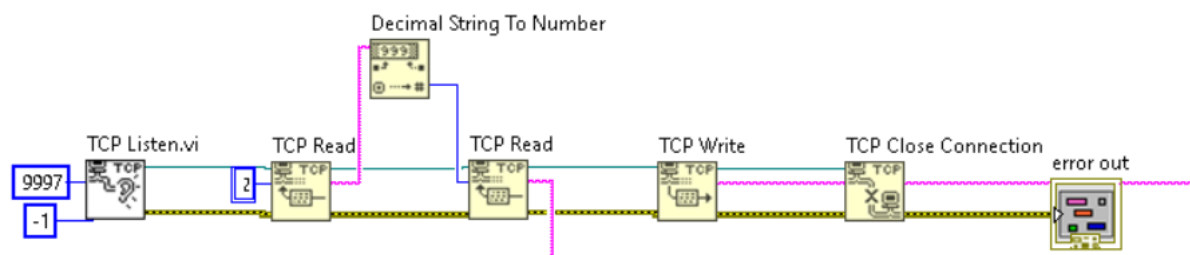


Figure 21 Server TCP/IP

The server listened on port 9997 using TCP Listen for clients to connect. Once connected, it first reads the size of the incoming data using TCP Read, followed by the concatenated username and password sent by the client. These are then processed through the Match Regular Expression that separates and validates the username and password. The server reads the stored credentials from the user using Read Delimited Spreadsheet from Users.txt. If a match is found,

it then sends a confirmation back to the client using TCP Write and the connection is then using TCP Close Connection.

5.0 Health and Safety Considerations

Health and Safety Considerations for an automated car wash controller

1. Vehicle Positioning

Ensure customers are provided with clear visual and written instructions on proper vehicle alignment. This minimizes the risk of equipment or vehicle damage caused by misalignment, helping to maintain smooth operations.

2. Warning Indicators

Install visible (LED lights) that activate if a vehicle is out of position. This system helps guide drivers to correctly align their vehicles, reducing the risk of accidental contact with machinery.

3. Emergency Stop Mechanisms

Place easily accessible emergency stop buttons near entry, exit, and driver-side areas of the car wash. These buttons enable immediate shutdowns in case of emergency, protecting both users and equipment.

4. Electrical Safety Measures

Equip all sensors, wiring, and proximity switches with waterproof and insulated covers to prevent exposure-related electrical hazards. This safety measure is crucial for reducing risks associated with water contact in the wash environment.

5. Routine Maintenance Protocols

Implement a regular maintenance schedule that includes thorough inspections, cleaning, and component testing. Routine check-ups help reduce the likelihood of unexpected breakdowns and ensures the car wash remains safe and functional.

6.0 Implementation

6.1 Hardware Requirements

Input Devices:

- **Proximity Sensors**



Figure 22 Proximity Sensor

Detect the vehicle's position as it enters and progresses through the wash bay. These sensors ensure the car is aligned correctly before each cycle starts, reducing the risk of equipment collision or misaligned washing. The system pauses and alerts the driver if any misalignment is detected, improving safety and efficiency.

Output Devices:

- **Indicator Lights**



Figure 23 Car Wash LED

Positioned at key points in the wash bay, these lights provide real-time feedback to the driver, signalling any issues such as misalignment or errors in the process. They also offer guidance for each stage of the wash to improve the user experience and minimize accidents.

- **Spray Nozzles**



Figure 24 Spray Nozzles

Specialized nozzles are used to dispense water, soap, or high-pressure water depending on the wash stage. These nozzles are designed to cover the entire vehicle surface uniformly, ensuring an effective and thorough wash

- **Dryer System**



Figure 25 Car Wash Dryer

A high-powered air blower system designed to remove water from the vehicle's surface following the rinse cycle. The dryer system is strategically placed to reach all areas of the vehicle and operates for a preset duration to ensure minimal water spots or streaks are left.

- **Display Panel**



Figure 26 Car Wash Display Panel

A user interface screen that guides customers through the wash process. It shows wash options, pricing, an estimated time for each stage, and displays "Thank You" and "Exit" messages upon completion. This panel enhances the customer experience by providing step-by-step information and reducing confusion or errors.

7.0 Conclusion

7.1 Limitations/Considerations

- The system will have difficulty cleaning heavily soiled vehicles without physical brushes.
- Correct positioning of the vehicle relies on sensors, which could lead to delays in case of misalignment of the vehicle.
- High initial cost for features like waterproofing which are necessary, it may be too costly for operators to afford.
- Vehicles with non-standard sizes or shapes might not work perfectly with the system.
- Any downtime due to maintenance or technical issues could disrupt operations.
- Highly dependent on a stable power supply as without one the system might be vulnerable in places with frequent outages.
- Regular sensor calibration and maintenance are essential to maintain system performance.
- While optimized, water usage could still pose challenges in areas with limited water resources.

7.2 Future Enhancements

- Integrate AI-powered sensors to improve vehicle positioning and detect areas that need more thorough cleaning.
- Develop a mobile app for users to control the system, schedule washes, and make payments.
- Use energy-efficient technologies for the drying system and spray nozzles to reduce energy consumption.
- Offer membership programs with added features like predictive maintenance based on wash data.
- Implement self-diagnostic systems to identify and fix hardware or software issues automatically.
- Incorporate renewable energy sources like solar panels to power the system which would lower operational costs.
- Design user interfaces that support multiple languages to cater to diverse customer needs.

- Add real-time water usage monitoring and recycling systems to minimize wastage.
- Include UV or antimicrobial cleaning options for added hygiene and safety.
- Develop modular system components for easier upgrades and cost-effective maintenance in the long run.

8.0 References/Appendix

8.1 User Manual

The Server VI should be runned before the Client VI. This is because when the client enters his Username and Password, the credentials are sent to the server to verify whether the user exists. If the Server VI is not running, the Client VI will not work because it depends on the server for authentication and processing.



Figure 27 Login or Register Page

From the main screen, please choose either Login or Register. If you have an existing account please chose Login, then you would be taken to the login page. If you don't choose Register, then you would be taken to the registration page to create a new account.

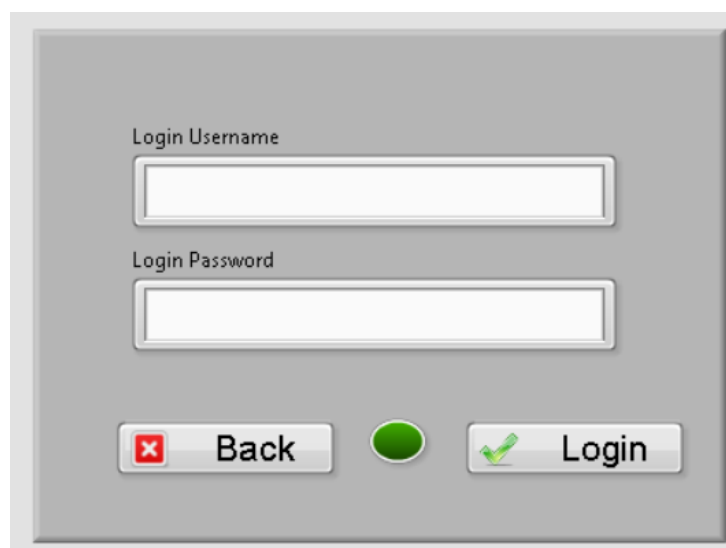
The image displays a login form within a gray-bordered window. The form contains two text input fields. The first field is labeled "Login Username" and the second is labeled "Login Password". Below these fields are three buttons. On the left is a "Back" button with a red square icon containing a white 'X'. In the center is a green circular button. On the right is a "Login" button with a green checkmark icon. The buttons have a 3D effect with shadows.

Figure 28 Login Page

After being directed to the Login page, you can enter your Username and Password. After entering your credentials, press the Login button to proceed with the authentication. If you need to revert to the previous screen, press the Back button.

The image shows a registration form with a light gray background. At the top, the text "Register Username" is followed by a white rectangular input field. Below this, the text "Register Password" is followed by another white rectangular input field. At the bottom of the form, there are two buttons: a "Back" button with a red 'X' icon and a "Register" button with a green checkmark icon.

Figure 29 Register Page

After entering the Register page, you will be prompted to enter your Username and Password in the appropriate fields. After filling in the details, click on the Register button to create a new account. To go back to the previous screen, click on the Back button.

The image shows a "Choose Wash Type" screen. At the top, the title "Choose Wash Type" is centered in a white box. Below the title, there are two options. The first option is "Deluxe Wash", which includes a red car icon, a "\$ 5" price tag, and the text "Deluxe Wash". The second option is "Economy Wash", which includes a blue car icon, a "\$ 3" price tag, and the text "Economy Wash".

Figure 30 Choose Wash Type Page

Upon successful login, you will be taken to the Choose Wash Type page, where you can choose between two services either Deluxe Wash or Economy Wash. You can click on either button depending on your preference for the wash type.

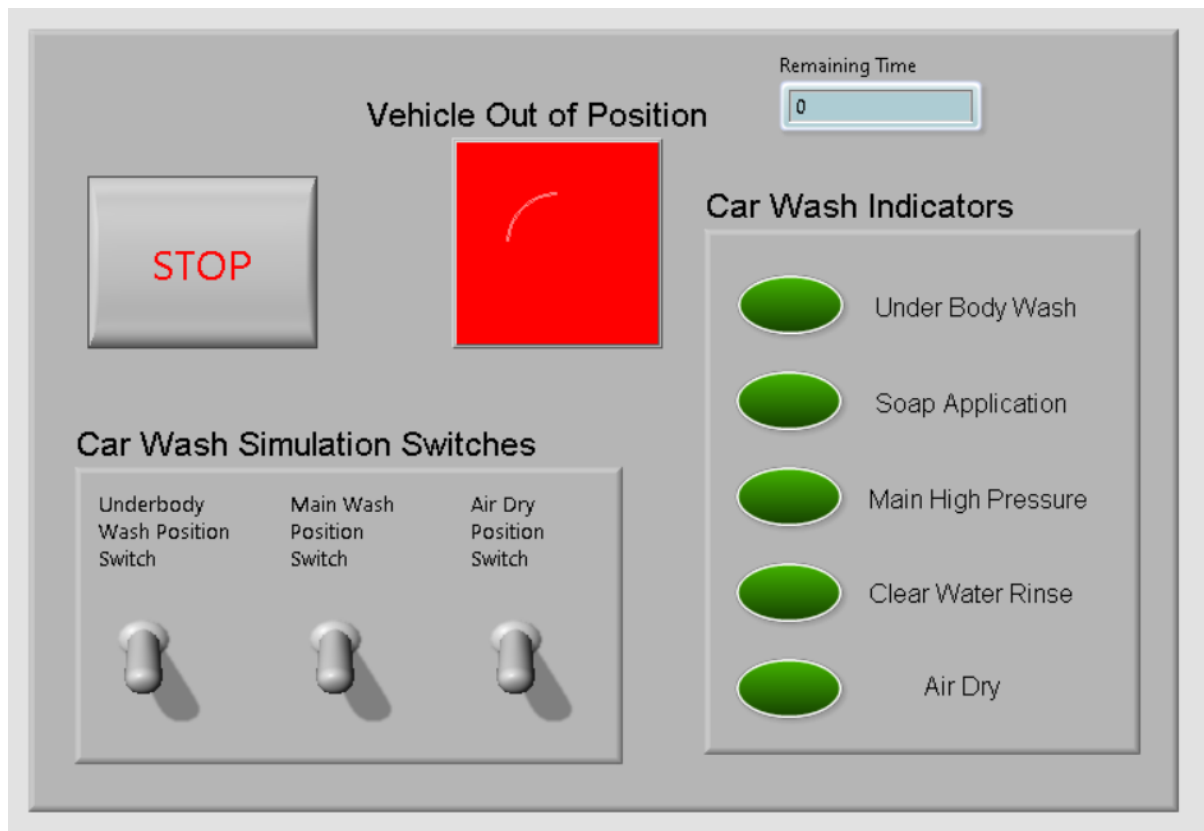


Figure 31 Wash Simulation Tab

After selecting the wash type, you will go to the Wash Panel. The Vehicle Out of Position LED lights up, showing that the vehicle is out of position and the wash will only take place upon the correct positioning of the vehicle. The Car Simulation Switches on the right will help determine the vehicle's position. You will also see a counter at the top right showing the remaining time of each wash process. The Car Wash Indicators will light up when a wash process is completed. The Big Stop Button is used to stop the entire program.



Figure 32 Undergoing Underbody Wash

If Deluxe Wash is selected, the first process would be the Underbody Wash. To indicate the vehicle is in position for the underbody wash, flip the Underbody Wash Position Switch. When the switch is flipped, the Vehicle Out of Position LED will go dark meaning the vehicle is in position. The timer on top, right-hand side will start to count down showing remaining time of the wash.



Figure 33 Vehicle Out of Position

If, during the wash, the vehicle moves out of position, you can indicate this by flipping the Underbody Wash Position Switch again. The Vehicle Out of Position LED will illuminate, indicating that the vehicle is no longer in position. The timer will also pause until the vehicle is repositioned. Flipping the switch again will resume the wash indicating that the vehicle has repositioned, and the Vehicle Out of Position LED will turn off and the timer will resume to continue the wash cycle.



Figure 34 Underbody Wash Completed

Once the Underbody Wash is complete, the Vehicle Out of Position LED will illuminate once again, signalling for the vehicle to be moved to the next position for continuation of the wash process. In relation to the Deluxe Wash, this next step is the Main Wash process. Along with it, the Underbody Wash LED will illuminate to indicate the completion of the underbody wash.



Figure 35 Main Wash Process

The Underbody Wash Position Switch must be turned off first to indicate that the vehicle has left the underbody wash position before the Main Wash process can start. Then, flip the Main Wash Position Switch to indicate that the vehicle is in the correct position for the main wash. Once the switch is turned on, the Main Wash process will start, which includes Soap Application, Main High Pressure Wash, and Clear Water Rinse, each for 5 seconds. If at any moment the vehicle moves out of position during any of the wash processes, just turn the corresponding Position Switch off to pause the process. This logic applies to all the wash processes.

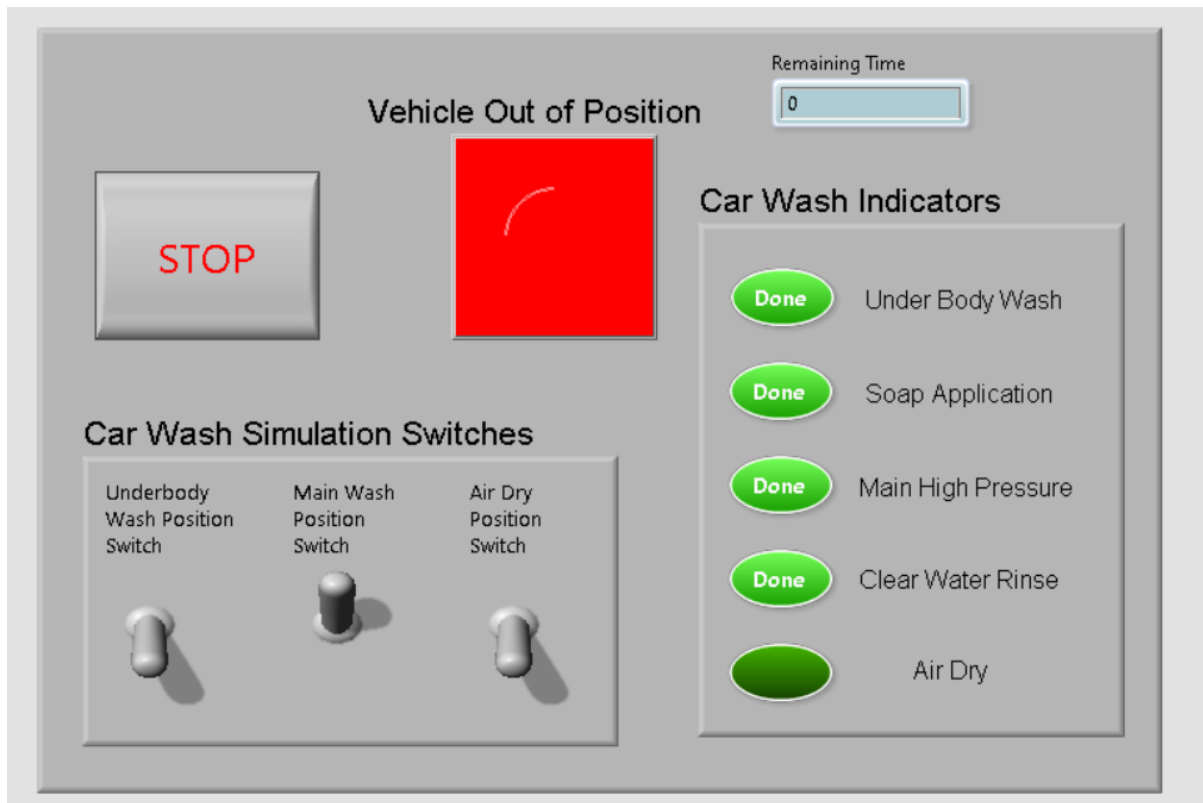


Figure 36 Main Wash Completed

Once the three Main Wash processes which are Soap Application, Main High Pressure Wash, and Clear Water Rinse have finished, the Vehicle Out of Position LED will light up to show that the main wash is over, and it is time to move the vehicle into the next position which is Air Dry in the case of the Deluxe Wash however in the case of Economy Wash only the main wash is to be done. Additionally, the LEDs of each of the Main Wash processes, comprising Soap Application, High Pressure Wash, and Clear Water Rinse, will turn on to indicate that each process of the main wash is complete.

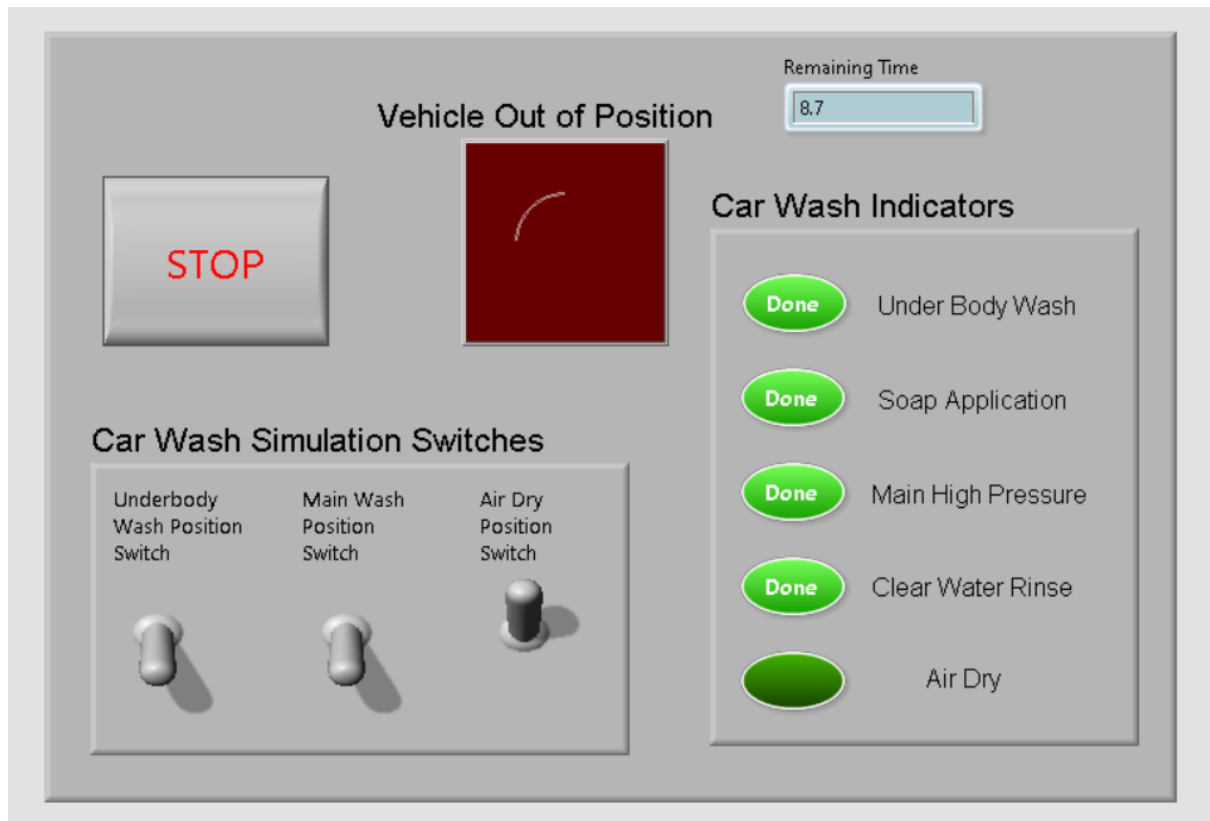


Figure 37 Undergoing Air Dry

The Main Wash Position Switch must be turned off first to indicate that the vehicle has moved out of the main wash position for the Air-Dry process to start. When the Main Wash Position Switch is off, flip the Air-Dry Position Switch to indicate that the vehicle is in the correct position for the air dry process. Once the Air-Dry Position Switch is flipped, the process of Air Dry will start and run for 10 seconds.



Figure 38 Air Dry Completed

Upon completion of the Air Dry process, the Vehicle Out of Position LED illuminates to signal the driver to exit out of the car wash because the wash is completed. Simultaneously, the Air Dry LED is light up to indicate the air dry process has been completed. Turning off the Air-Dry Position Switch shows that the vehicle has left the car wash. The program then saves the log data of the car wash and sends it to the server. Then the program will reset, and you will be brought back to the Login or Register page once again, showing that the car wash is ready for the next vehicle to take a wash.

In the context of Economy Wash, after the completion of the Main Wash process, the Vehicle Out of Position LED lights up, signaling that the wash is over, and the vehicle must leave the car wash. To indicate the car has exited the car wash, it can be done by switching off the Main Wash Position Switch. The program will then save the log of car wash data and send it to the server. Then, you will be taken back to the page for Login or Register, indicating that the car wash is ready for the next vehicle.

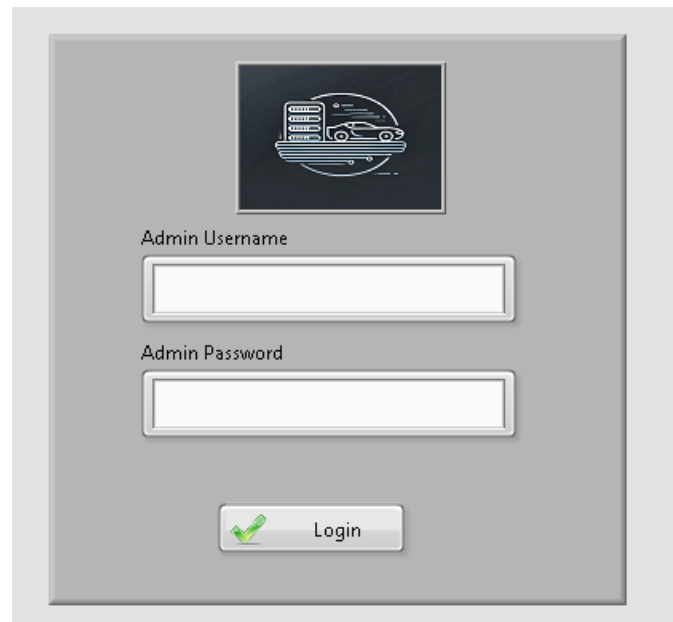


Figure 39 Admin Login Page

On the server side, it will prompt you to log in by entering your username and password. After filling in the credentials, click the Login button to authenticate and gain access to the functionalities on the server.

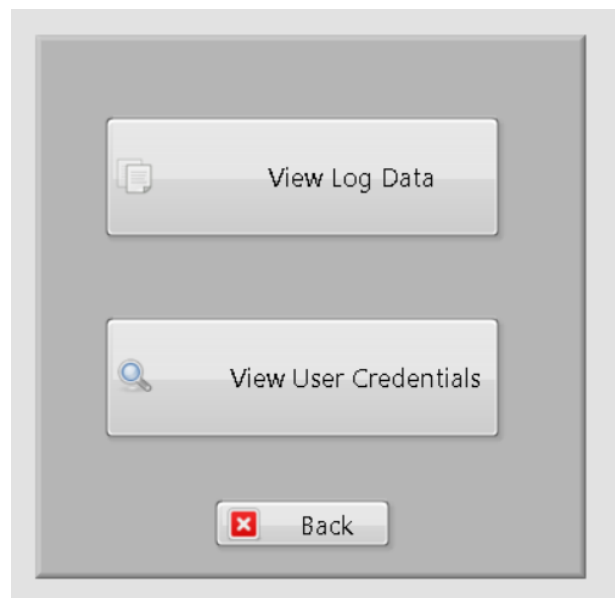


Figure 40 Choose Function Page

After successful login, you will have two options: View Log Data and View User Credentials. You can choose your desired option by pressing the corresponding button. To go back to the previous screen press the back button.

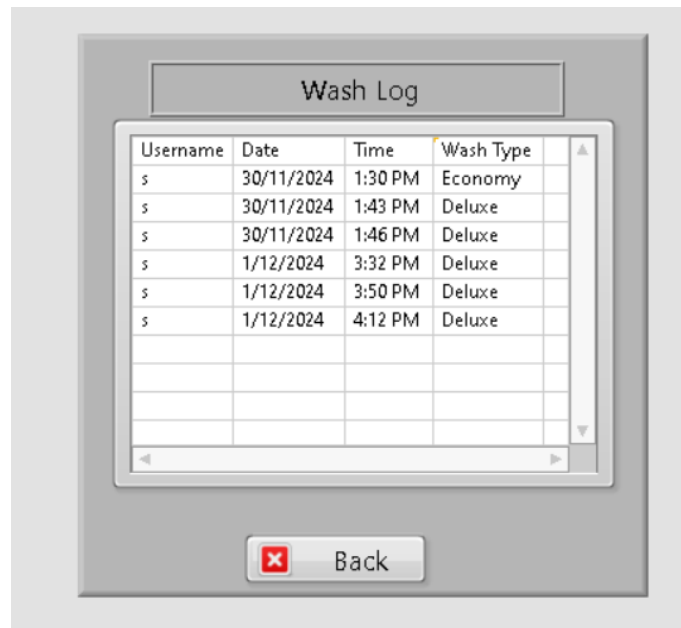


Figure 41 View Wash Log

If View Log Data is clicked, it will route to the Wash Log Page where the table would show data such as Username, Date, Time, and Wash Type. Clicking the back button would bring you back to the previous screen.

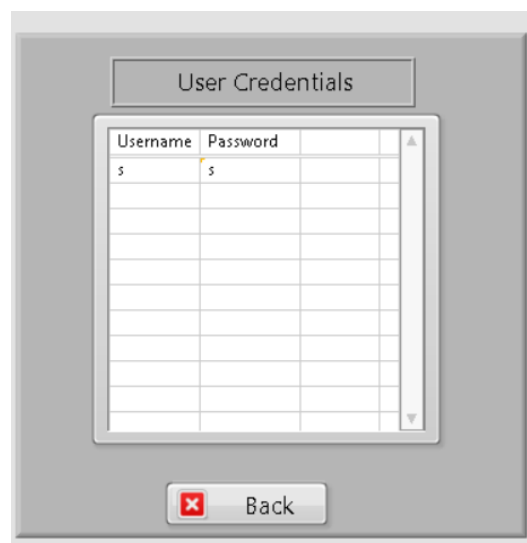


Figure 42 View User Credentials

If View User Credentials is clicked, it will bring you to a page where you can view the Username and Password of all registered customers. To go back to the previous screen, simply press the Back button.

8.2 References

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