FACULTY OF COMPUTING AND INFORMATION TECHNOLOGY Assignment

SMART PARKING SYSTEM

BAIT2123 Internet of Things

202401

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Programme : RDS

Tutorial Group : 3

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1.0 Description of System

1.1 Description

The Smart Car Parking System is an intelligent solution that utilizes sensors, cameras, and automated controls to improve parking management. The system uses infrared (IR) sensors to track parking slot occupancy in real time, delivering precise and up-to-date information on available parking spaces. When a vehicle approaches the barrier or gate, the infrared sensor recognizes its existence. At this stage, the system turns on a camera to take an image of the car. This image is captured before the gate opens to ensure correct identification or documentation of the car entering the parking space. The servo motor, which is the barrier gate, does not activate until the picture is successfully captured, at which point it lifts the barrier or opens the gate to allow the vehicle past. This provides an additional layer of protection and monitoring to the parking system. Drivers can monitor available parking spaces on an LCD panel located at the parking entry, which is updated in real time using IR sensor data. The screen displays vacant spaces, allowing cars to rapidly discover available parking spots, saving time and decreasing congestion. At the same time, administrators can monitor the parking lot remotely using a Node-RED dashboard. This web-based dashboard consolidates data from infrared sensors and surveillance cameras, displaying real-time parking occupancy and vehicle photos as they enter. The interface is user-friendly, giving managers a clear overview of parking utilization and security, allowing them to manage the lot more efficiently.The system's automatic gate control, real-time updates, and surveillance improve the efficiency and security of parking management. It offers a modern solution that reduces traffic, saves time, and enhances the entire experience for drivers and parking lot managers.

1.2 Objective

The Smart Car Parking System is designed to efficiently monitor the availability of parking slots using IR sensors. It displays the real-time status for both parking slots on an LCD screen for drivers and a Node-RED dashboard for administrators. This dual approach enhances parking management by providing quick access to available parking information for users and enabling internal control and monitoring for administrators. The system aims to reduce the hassle for parkers by indicating available slots upfront, while providing administrators with a comprehensive view of parking utilization and also controlling the barrier gate through the dashboard.

1.3 Business Value / Advantages

- **Reduced Congestion :** Drivers are informed of available parking spaces quickly, reducing traffic congestion inside parking lots. This not only improves the flow of traffic but also minimizes the time spent searching for parking, leading to a smoother driving experience.
- **Convenience :** Real-time updates provide drivers with instant information about available parking spots. This reduces the frustration associated with searching for parking and enhances the overall convenience for users, making their parking experience quicker and stress-free.
- **Reduced Environmental Impact :** By minimizing the time vehicles spend circling around for parking, the system helps reduce fuel consumption and lower carbon emissions, contributing to environmental sustainability.
- **Adaptability for Smart City Integration :** The system is future-proof and can be easily scaled or integrated into larger smart city initiatives, allowing cities to develop smarter infrastructure for public and private parking facilities.
- **Increased Customer Satisfaction** : Providing drivers with a convenient way to find parking quickly can significantly enhance their overall experience. Satisfied customers are more likely to return, increasing loyalty and repeat business for facility owners.

2.4 Targeted Users

- **Drivers :** The system enables individuals to quickly locate available parking spots, allowing drivers to spot a parking slot from a distance based on the LED light indicators.
- **Parking Lot Administrators :** The Node-RED dashboard allows administrators to oversee the occupancy of parking lots in real time and also control the system.
- **Parking Facility Owners :** These facilities benefit from the system by providing a seamless parking experience to their users, ensuring that parking management is optimized and reducing the strain on staff and resources.

2.5 Why does everyone need our system?

Parking in busy areas is often stressful, time-consuming, and frustrating for drivers. Our Smart Car Parking System provides an efficient solution by instantly informing drivers of available parking spots, eliminating the need to circle around in search of a space. This not only reduces stress but also enhances the overall parking experience, making it faster and more convenient.

For parking lot owners and administrators, the system minimizes the need for manual oversight by providing real-time data on parking lot occupancy, reducing operational costs, and improving management efficiency. With the ability to scale and integrate into smart city initiatives, our system offers a modern, forward-thinking solution to parking challenges for everyone.

2.0 System Design

2.1 Reference System

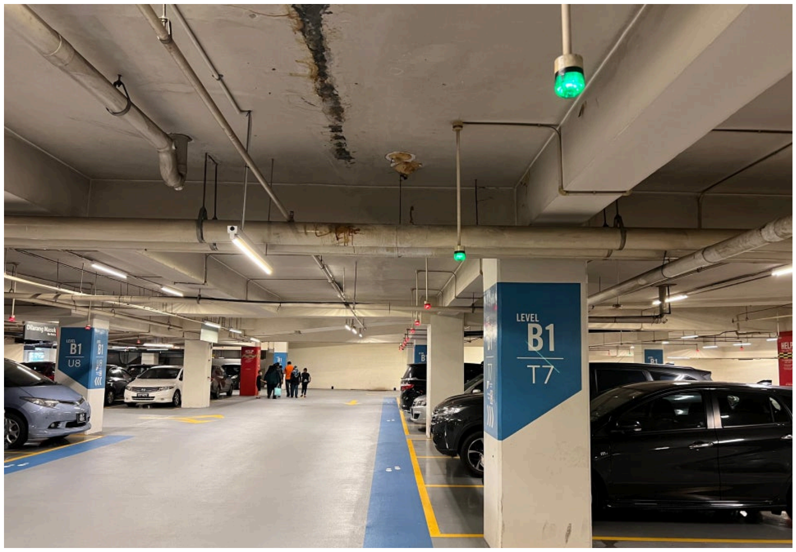
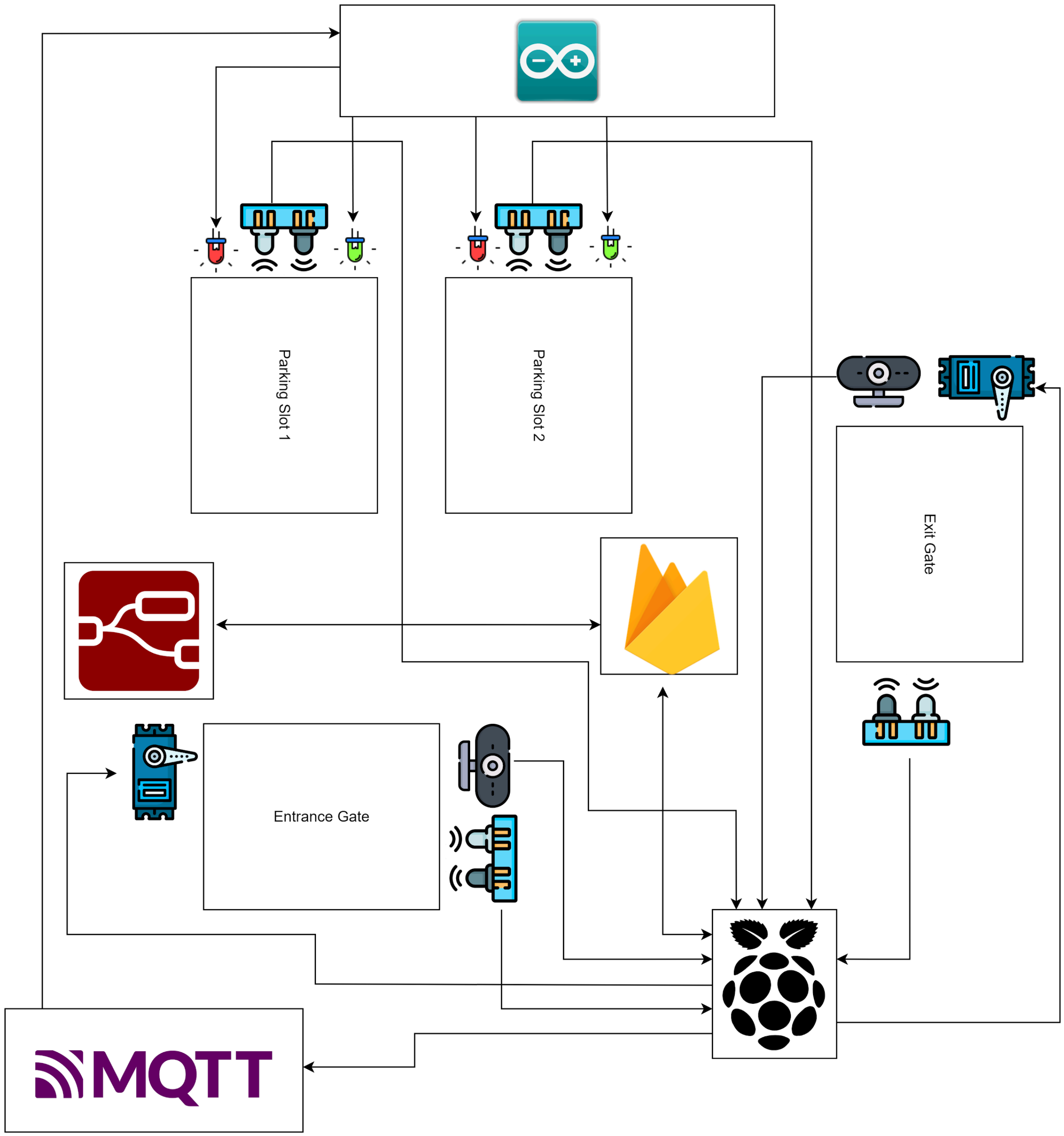


Figure 2.1.1 Sunway Pyramid Car Park

The Smart Car Parking System is inspired by automated parking management systems commonly found in urban environments, such as those at Sunway Pyramid and Mid Valley Megamall. These systems utilize sensor networks to detect available parking spaces and relay this information to both drivers and administrators through user-friendly interfaces like digital displays. A prime example is the parking guidance systems seen in shopping malls and airports, which use light indicators—green meaning a slot is available and red indicating it's unavailable—to efficiently guide drivers to vacant spots. This improves both convenience and traffic flow within parking facilities.

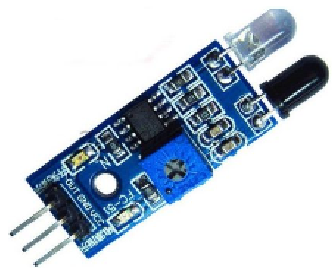
Moreover, these systems often combine cameras, sensors, and real-time data processing to monitor parking availability, track vehicle movements, and automatically manage parking fees. The integration of cloud-based solutions allows for remote monitoring, data storage, and analysis, providing parking administrators with valuable insights into parking patterns and trends. However, we do not implement parking fees in our system as the primary goal is to demonstrate the core functionalities of parking slot detection and efficient monitoring, rather than managing payments.

2.2 Overall IoT Solution Design



2.3 Functions/ Modules Descriptions

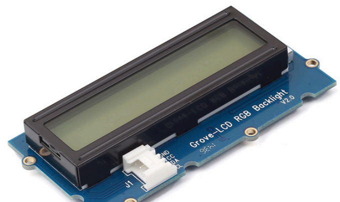
2.3.1 Sensor Data Acquisition Module

	
IR sensors (4 units)	Camera (2 units)

The Sensor Data Acquisition Module of the smart car parking system collects and processes data from a variety of input sources, including four infrared (IR) sensors and two cameras. These infrared sensors are carefully installed at the parking lot's entrances and exits to monitor vehicle movement. When a car approaches the entry or exit, the IR sensors send electrical impulses to the microcontroller, which uses this data to determine the car's position. Each sensor is connected to the microcontroller's allocated GPIO pins, allowing for real-time detection and response. The data from the IR sensors is critical for regulating the two servo motors that control the entrance and exit gates, ensuring that they open and close at the proper moments when a car is spotted. This automated system ensures smooth traffic flow throughout the parking lot while reducing the need for human involvement. In addition, an LCD and four LEDs act as indicators, updating users in real time on parking availability and system functions.

In addition to the IR sensors, the module contains two cameras that improve the system's functionality. These cameras, which are located at the parking lot's entrances and exits, record high-quality photos of vehicles entering or exiting the lot. This visual data can be used for a variety of applications, including license plate recognition and object detection, which improves monitoring and security features. To ensure reliability, error management is included into the image capture process. If the camera fails to capture an image while calling the capture_image(camera_index, filename) function, an exception is thrown to alert the system to the problem. This protection reduces disturbances in the car detection process and makes troubleshooting easier if a capture failure happens. Furthermore, the module keeps track of car enters and exits, with a sufficient number of sample records, such as two car entry or three car exit records in the system, to ensure a strong dataset for analysis and operational improvements. The combination of cameras and IR sensors creates a comprehensive data collecting system capable of precisely tracking vehicle movements, managing gate operations, and enabling additional capabilities such as image-based identification or surveillance. Together, these components create a highly efficient and automated parking management solution.

2.3.2 Actuator Execution Module

		
Servo Motor (2 Units)	16 x 2 LCD (1 Unit)	Red LED (2 units) Green LED (2 units)

The Actuators Execution Module is an important part of the smart parking system. It manages key elements like the servo motor, LCD display, and LED status indicators. The Servo Motor Control function operates the motor that opens and closes the barrier gate at the parking entrance and exit. This function is triggered by infrared (IR) sensors that detect when a vehicle is nearby. When a car is detected, the motor lifts (opens) or lowers (closes) the gate, allowing smooth vehicle access. The motor's status is stored in a Firebase database, which allows for real-time monitoring. Additionally, users can manually control the motor through a dashboard, making it easier to manage during busy times or emergencies.

The LCD Display Control function shows parking slot availability on an LCD screen. It receives real-time information from the IR sensors in each parking slot. When a vehicle takes a slot or leaves, the display updates to show how many slots are available. This feature helps drivers quickly find parking, reducing congestion. The LED Status Indicator Control manages lights that show the status of parking slots by changing colors: green means available, and red means occupied. The LED status updates via MQTT communication, where the Raspberry Pi sends data from the IR sensors to the Arduino, which controls the LED lights. This integration ensures that the lights accurately reflect the parking slot status, improving reliability and user experience.

2.3.3 Sensor Data Processing Module

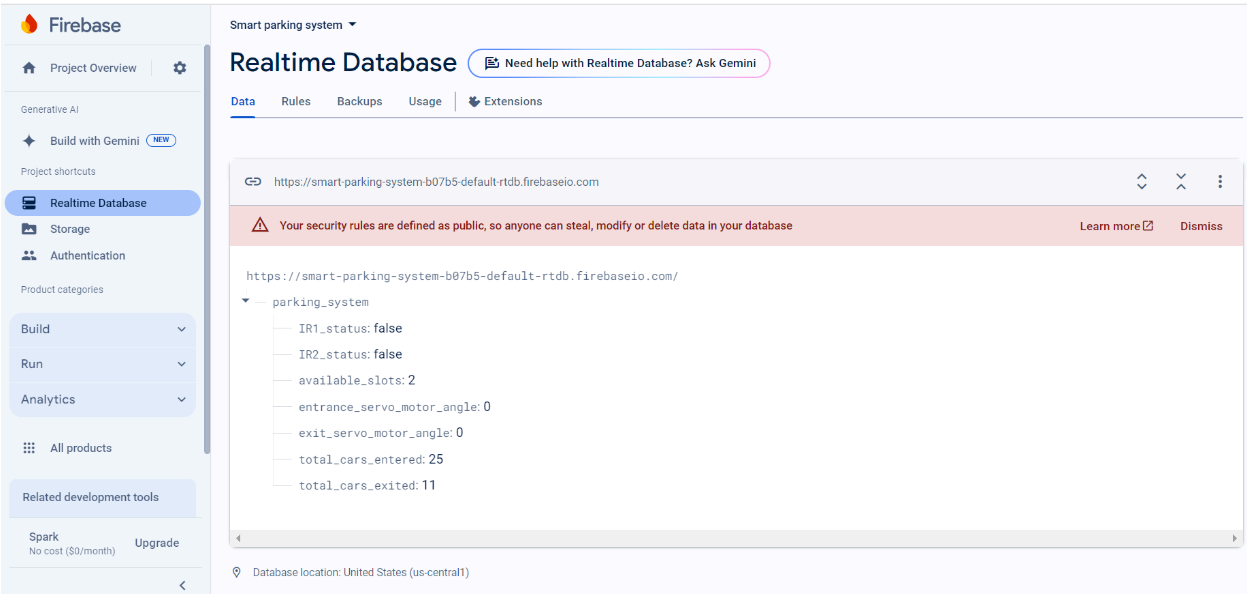


Figure 2.3.1 Realtime Database of Firebase

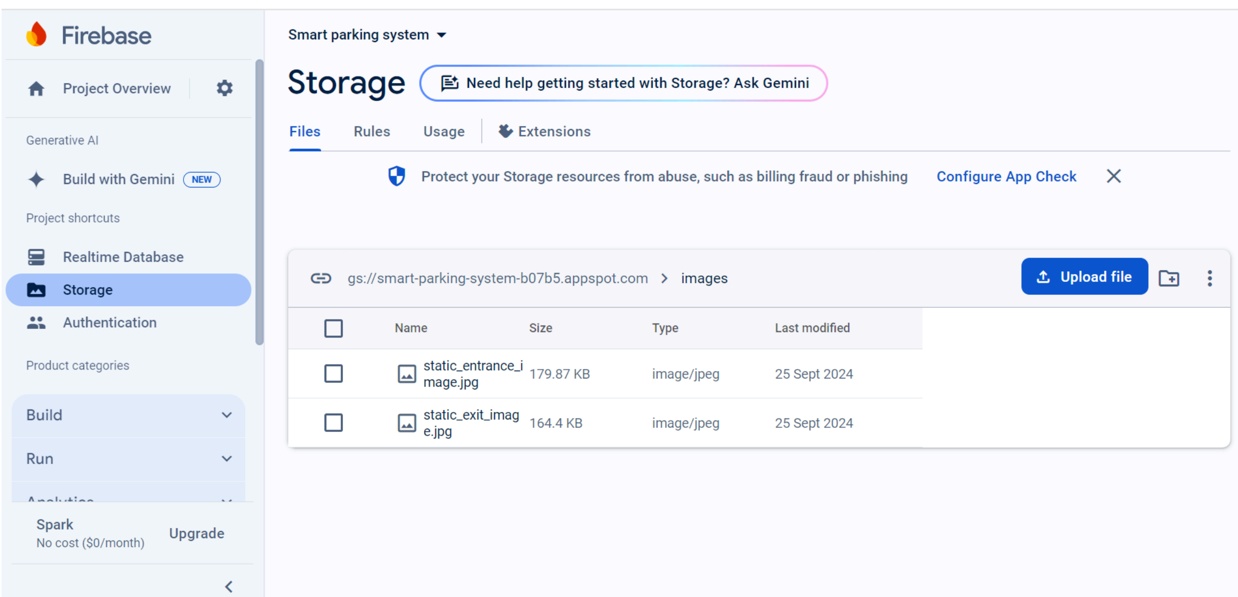


Figure 2.3.2 Storage of Firebase

The Sensor Data Processing Module efficiently manages parking slot availability and vehicle flow in real-time using IR sensors, servo motors, cameras, and Firebase. The system deploys Firebase cloud services for storing, updating, and retrieving data, utilizing Firebase Storage for images captured at the entrance and exit, while the Realtime Database stores key operational data such as IR1_status, IR2_status, available_slots, entrance_servo_motor_angle, exit_servo_motor_angle, total_cars_entered, and total_cars_exited. This data is updated in real-time while the system is running, enabling accurate monitoring of parking conditions. For analysis and reporting purposes, captured data, including vehicle flow and parking occupancy, is retrieved by Node-RED from Firebase, facilitating optimization of management and ensuring smooth operation.

2.3.4 User Interface Module

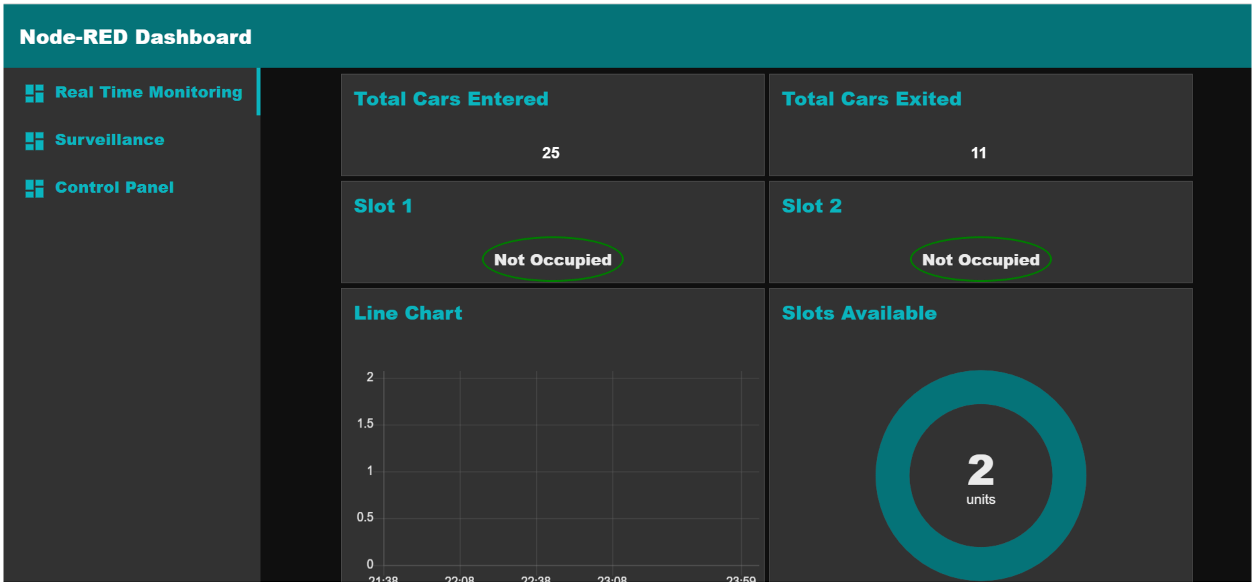


Figure 2.3.3: Real time monitoring tab of the user interface

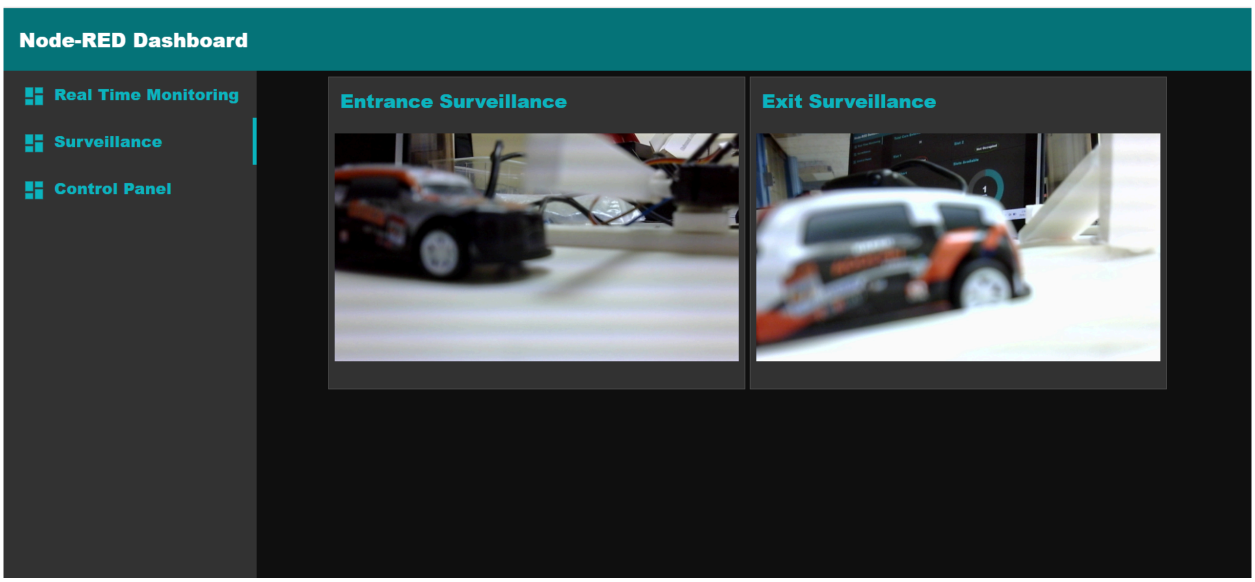


Figure 2.3.4: Surveillance tab of the user interface

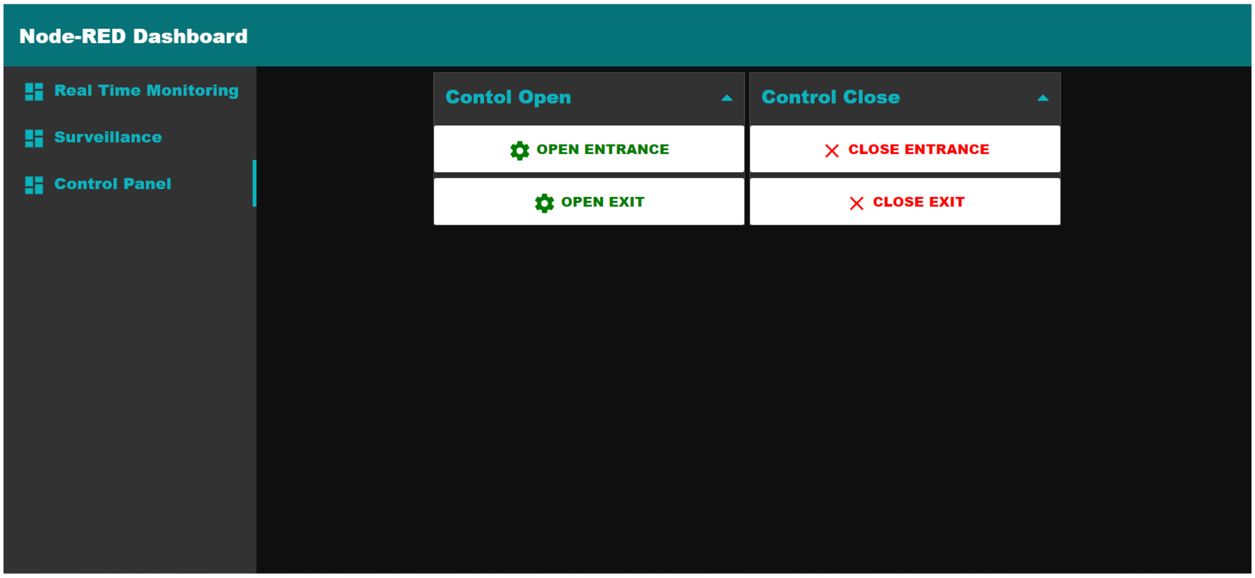


Figure 2.3.5: Control panel tab of the user interface

A website was created using Node-red for the user interface of the parking system. In the website, there are 3 options at the side bar on the left containing the real time monitoring, surveillance, and control panel options. In the real time monitoring tab, Information such as the total number of cars entered and exited, status of each slot to show if it is occupied, and some visual representations of the slots can be viewed. This real time monitoring system allows the authorities to monitor the system easily without any hassle in real time and it also allows normal users to know about the availability of the parking slots easily. For the surveillance tab, pictures of the last entered and exited car can be viewed here for car identification. This allows the authorities to monitor if there are any suspicious vehicles in the premises of the car park. To manually control the barrier system of the car park, the authorities can go to the control panel tab to remotely open or close the entrance or exit barrier. Any suspicious vehicle can be stopped from exiting by remotely closing the exit barrier of the car park. Thus, this strengthens the security of the car park to a certain extent.

2.4 Pictures of prototype design

2.4.1 Car park Design

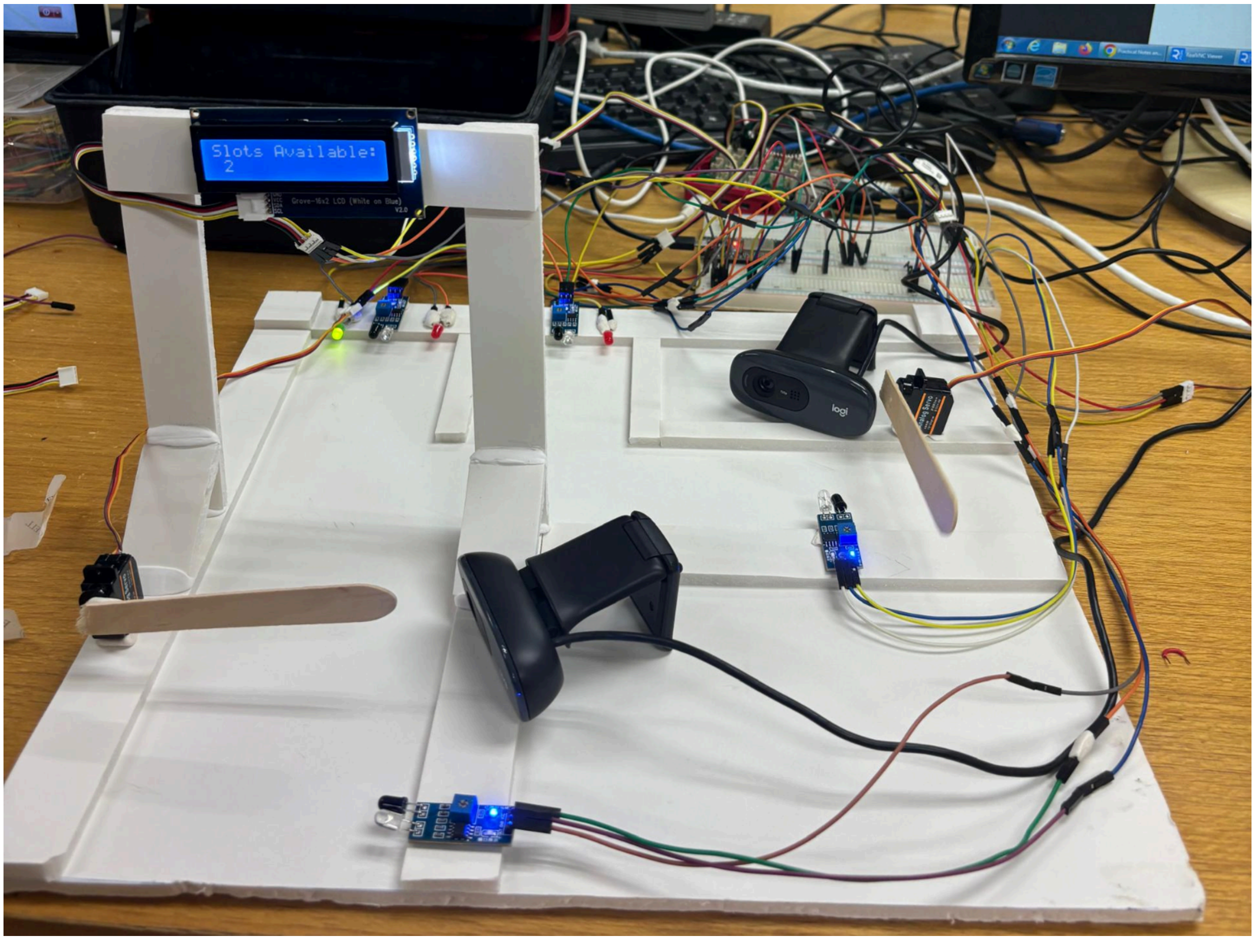


Figure 2.4.1: The prototype design of the car park

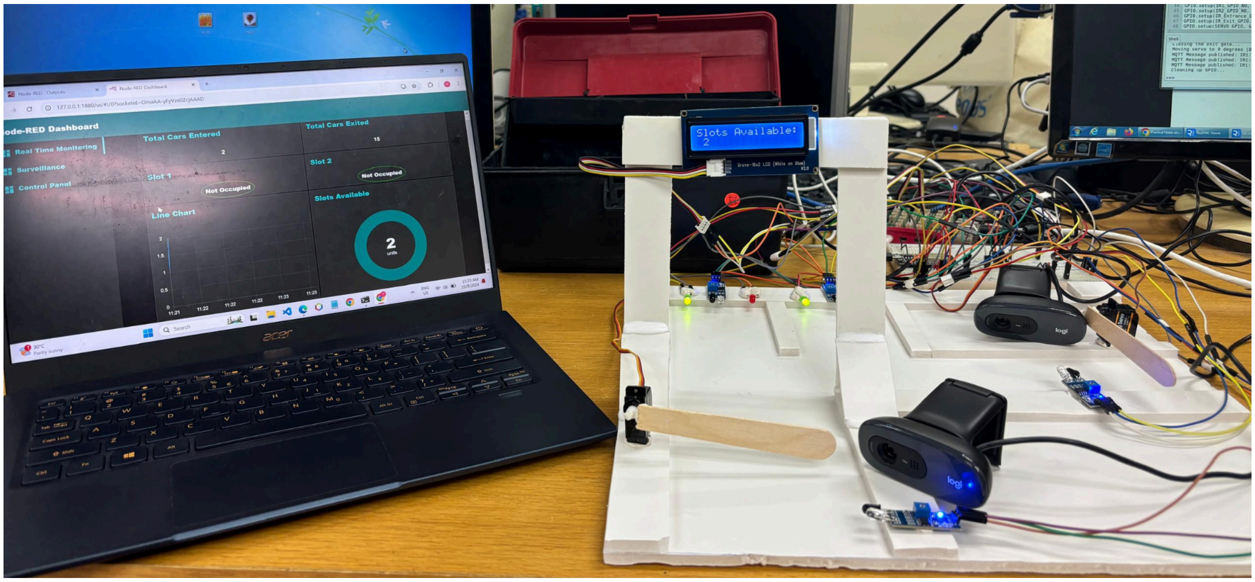


Figure 2.4.2: The prototype with user interaction web-based system

2.4.2 Node-Red

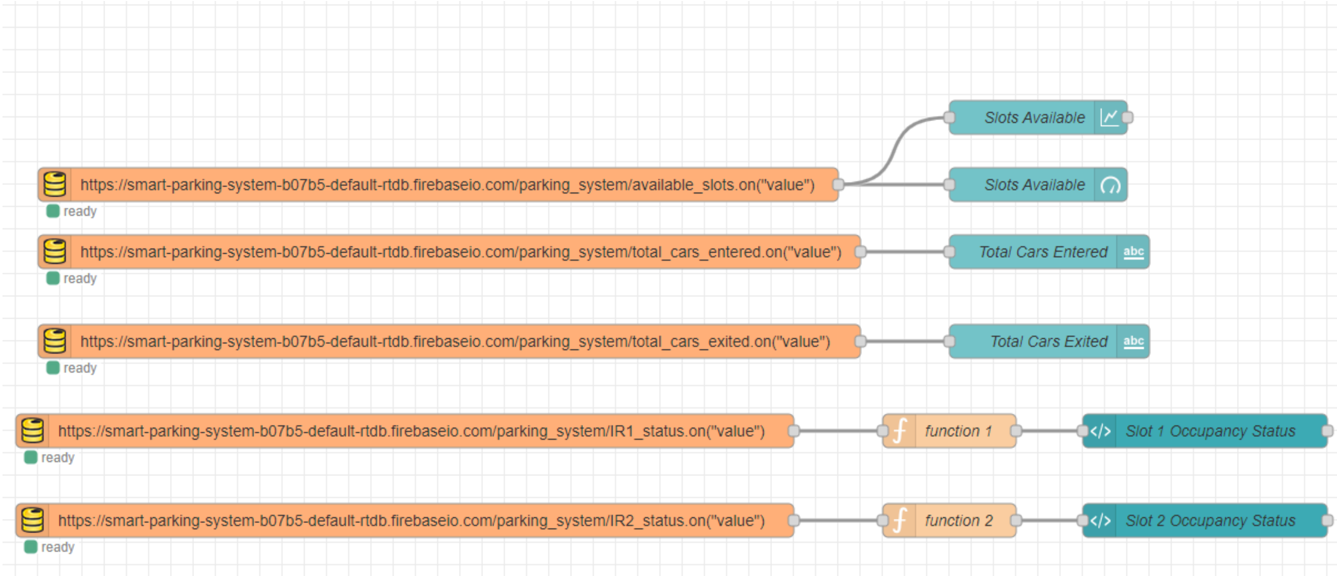


Figure 2.4.3: Real time monitoring tab design

This part of the design of the Node-Red is responsible for letting the authorities or the drivers to view basic information about the car park. It consists of a line chart and a donut chart about the availability of slots. This part of the design also adds in the features of letting the authorities or the drivers to view the total cars entered, total cars exited, and occupancy of each slot.

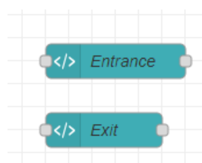


Figure 2.4.4: Surveillance tab design

These 2 elements here are to show the last picture of the car taken at both the entrance and exit of the car park.

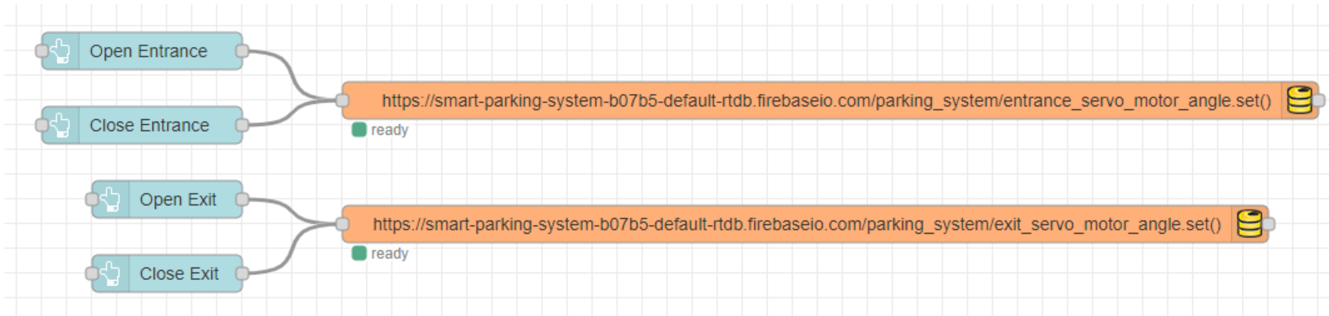


Figure 2.4.5: Control panel tab design

This part of the design of the Node-Red is to let the authorities control the barrier system of the car park system. The process of opening and closing the barrier of entrance and exit is made easy with just a click of a button to manipulate the barrier.

3.0 User Manual

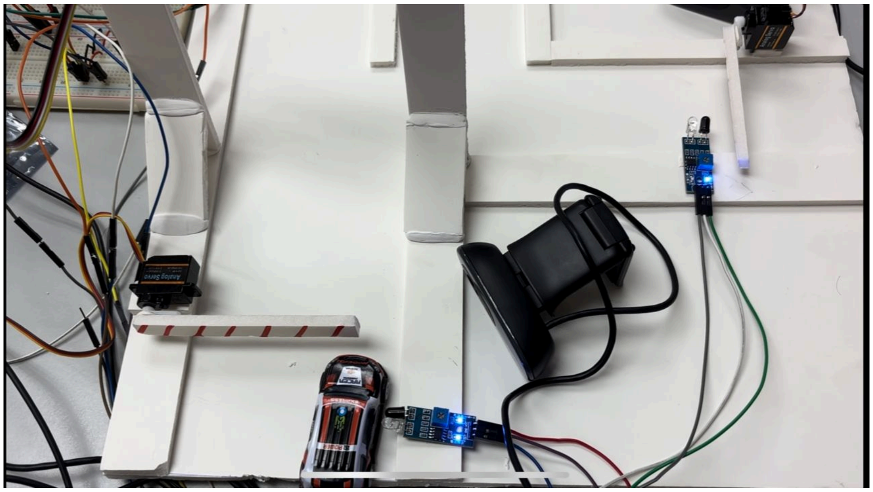


Figure 3.1: Entrance of car parking system

Figure 3.1 shows that when a car approaches the entrance, the IR sensor detects its presence, triggering the camera to capture an image of the vehicle. Subsequently, the servo motor rotates 90 degrees to open the gate. After a delay of 1.5 seconds, the servo motor returns to 0 degrees to close the gate.

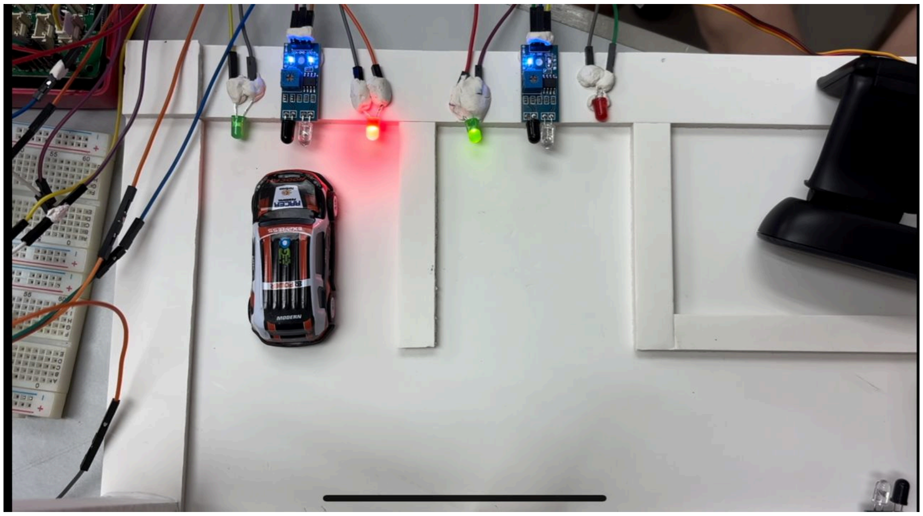


Figure 3.2: Parking slot 1 occupied

Once the car enters after passing through the entrance gate, the car will then park in either one of the parking slots provided. Before the car parks at one of the slots, a green light will be lighting up initially which indicates that the parking slots are empty. This helps to inform that if green light is emitting then it means the parking slot is empty and can be parked. Once the car is parked at one of the empty slots, a red light will be emitted indicating that the parking slot is occupied with a car as shown in Figure 3.2.

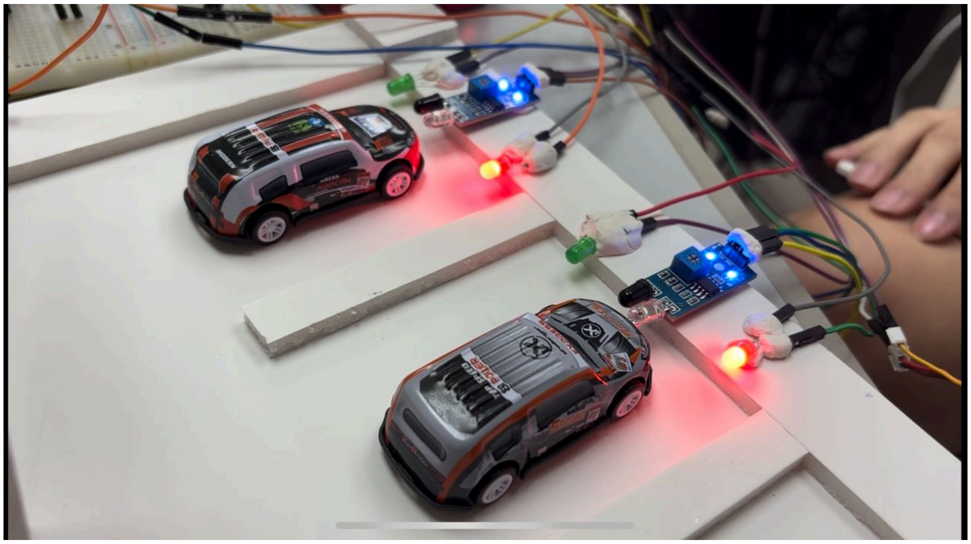


Figure 3.3: Parking slot 1 and slot 2 occupied

Figure 3.3 shows that two cars are parked and red lights which the IR sensors detect the cars in front and emitted indicating the two parking slots, parking slot 1 and parking slot 2 are occupied.

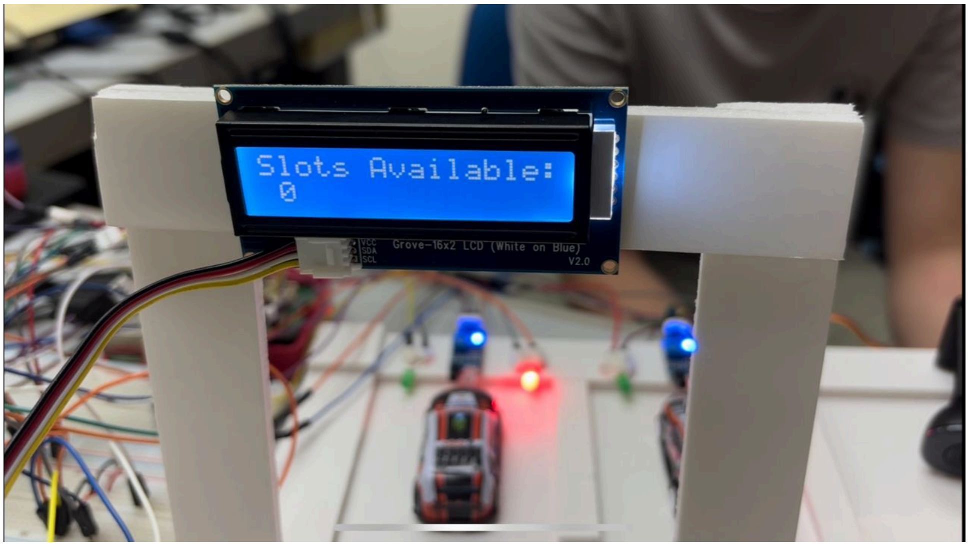


Figure 3.4: LCD display

The LCD display will show the availability of parking slots at the entrance, helping drivers to know whether there are slots available for parking. This feature reduces congestion and minimizes the time spent searching for a parking space. As shown in Figure 3.4, when 2 slots are occupied, slots available are 0.

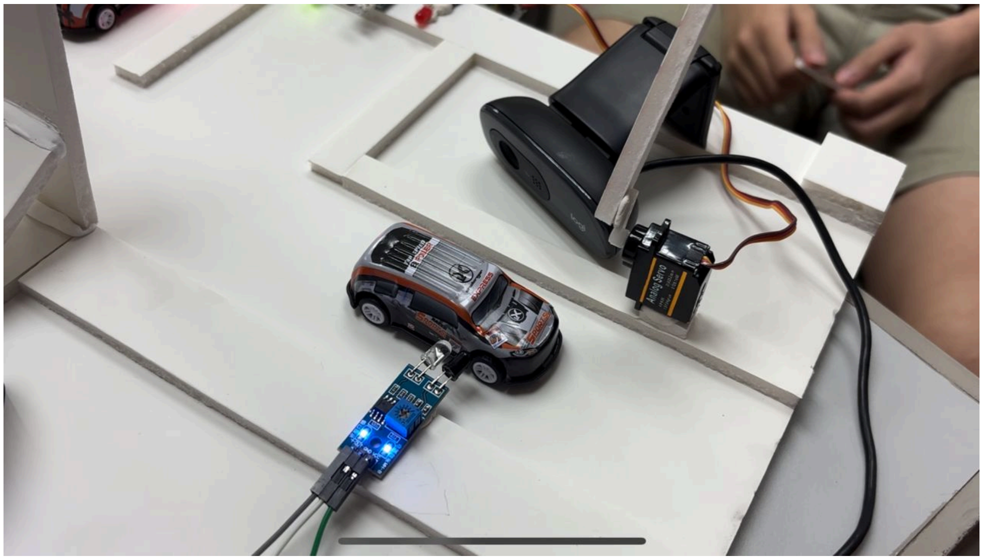


Figure 3.5: Exit of car parking system

When the IR sensor detects the presence of a car, the system activates the camera to capture a photo of the vehicle, which is then saved to Firebase storage. The barrier gate will only open once the photo has been successfully taken. Then the car can exit the parking and the gate will be closed.

4.0 Task Allocation

Task	Person in charge
1. System Architecture Design	Everyone
2. Sensor and Actuator Integration	Yam Jason, Ashantha, Wong Yee En
3. Sensor Data Acquisition	Yam Jason, Wong Yee En, Vithiya
4. Firebase Integration	Wong Yee En
5. Node-RED Dashboard Development	Yam Jason, Wong Yee En, Ashantha
6. Arduino Integration	Yam Jason, Ashantha, Vithiya
7. Documentation	Everyone

5.0 Lessons that we have learned / Problems that we faced

1) LED Lighting Issue

The LED lights did not reveal, so we were unsure whether they were broken or incorrectly put. This misunderstanding slowed down debugging because we could not tell if the problem was with the LEDs or the wiring. We learned how to test individual components before merging them into the system. This helped us avoid guessing whether the problem was with the hardware or the connections, allowing us to focus on the genuine issue more quickly.

2) Servo Motor Glitching

The servo motor vibrated and moved erratically, rotating in unexpected directions despite proper coding. We eventually discovered that this was due to hardware limitations, such as maximum angles or loose connections, rather than coding faults. We realized how important it was to consider physical limitations, such as movement restrictions, and to verify connections on a regular basis during troubleshooting to maintain smooth operation.

3) Difficulty with MQTT and Firebase Data Retrieval

We had trouble implementing MQTT methods on the Arduino ESP32 to access Firebase data. This slowed our progress as we attempted to make real-time updates operate properly. This taught us the necessity of properly understanding how communication protocols such as MQTT and Firebase work. Testing early and becoming familiar with the libraries in use would have saved us time and effort.

4) Node-RED Interface and Data Display Challenges

Using Node-RED to create an interactive user interface presented several challenges, particularly with displaying data correctly and arranging the design. There were instances where data was displayed incorrectly, and the layout was not always intuitive. Additionally, displaying images retrieved from Firebase proved difficult since it required handling the URL of the stored images, which complicated the process of integrating them into the UI. These challenges highlighted the importance of careful planning in both data synchronization and UI design. Early prototyping and validation of real-time data feeds, including the proper handling of image URLs, improved the user experience and minimized errors.

5) Camera Setup for Image Capture

Initially, the camera captured black images, indicating it had not fully initialized or started up. This caused problems with image capture. After identifying that the issue was due to the camera not being ready, we added a delay before capturing the image, allowing the camera to initialize properly. With the delay in place, the camera successfully took normal pictures, highlighting the importance of ensuring proper initialization for real-time image capture in such applications.

6) Code Integration and Compilation Challenges

We created separate sections of the system separately, thus combining them produced complications, with some parts working while others failing. This slowed down the integration process and increased the likelihood of errors. We discovered that integrating and testing components regularly during the development process helps to avoid errors during final compilation. It is critical to ensure that all project components function together seamlessly.

6.0 Conclusion

The Smart Car Parking System successfully demonstrates how the Internet of Things may improve parking management by providing drivers and managers with real-time updates on available slots. The system increases parking efficiency and lowers congestion by integrating sensors, cameras, servo motors, and an easy-to-use Node-RED dashboard. Although we encountered difficulties with hardware integration, data retrieval, and interface design, these impediments taught us significant lessons that improved our understanding of both the technical and practical elements of the project.

The system's modular design enables scalability and future upgrades, making it suitable for inclusion into smart city infrastructures. Overall, the project met its objectives by providing a modern, efficient parking management solution that benefits both drivers and facility owners. With additional improvement, the system might be used in real-world applications to improve parking experiences while lowering operational expenses.

Lastly, we want to express our sincere thanks to our tutor, Dr. Tew Yiqi, for his invaluable guidance during this assignment. His support and advice helped us overcome the challenges we encountered and played a key role in the successful completion of our project.