# UTTARA UNIVERSITY

Department of Electrical & Electronic Engineering

**Title**

**Design, Analysis and Implementation of Automatic Car parking system**

**<u>Submitted by</u>**


Md. Ariful Haque
ID: 2213171064

Md. Minarul Islam
ID: 2213171056

Nusrat Jahan Moni
ID: 2213171019

# Declaration

We hereby do solemnly declare that the work presented in this project has been carried out by us and has not been previously submitted to any other university for an academic degree. This project being submitted as a particular fulfillment of the requirement for the degree of Bachelor of Science in Electrical and Electronic Engineering commenced from Fall- 2024 of Uttara University is the result of our own project work. We hereby declare that no part of this project consists of materials copied or plagiarized from other published or unpublished source have either been put under quotation or duly acknowledged with full reference in appropriate places.

Signature of Author's

06.01.25

Md. Ariful Haque
ID: 2213171064
B.Sc. in EEE
Uttara University

06.02.25

Md. Minarul Islam
ID: 2213171056
B.Sc. in EEE
Uttara University

06.02.25

Nusrat Jahan Moni
ID: 2213171019
B.Sc. in EEE
Uttara University

Signature of Supervisor

11.02.2025

Md. Sahinur Rahman
Lecturer
B.Sc. in EEE
Uttara University

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# Abstract

Automated car parking (ACP) systems represent a significant advancement in urban transportation, designed to optimize parking efficiency, reduce human intervention and address the growing demand for parking spaces in crowded cities. These systems utilize a combination of Arduino, sensors, robotics to enable vehicles to park autonomously without driver input. The primary objective of ACP systems is to maximize space utilization, decrease traffic congestion and enhance convenience for users. There are two main types of automated parking systems: Automated Valet Parking (AVP), where the driver drops off the vehicle and automated parking garages, where robotic systems park and retrieve vehicles within multi-story structures. While ACP systems offer numerous benefits such as increased parking capacity, reduced search time for parking spots and enhanced safety, they also present challenges such as high installation costs, integration with existing infrastructure, and accessibility issues. This abstract outlines the key features, benefits, and challenges of automated car parking, and highlights its potential to transform urban parking solutions through technological innovation.

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# Chapter 1
# Introduction

## 1.1 Introduction

Automated car parking refers to an advanced system that enables vehicles to park themselves without human intervention. This system uses a combination of Arduino Uno, sensors, Servo Motor, software to guide the car into a parking space. The concept aims to optimize parking in congested areas, enhance convenience, and improve space utilization in parking facilities.

Key components of an automated parking system (APS) include:

- Sensors: These are used to detect obstacles, identify available parking spots, and measure distances between the vehicle and other objects.
- Control Systems: These systems process information from sensors and cameras, controlling the vehicle’s movements and guiding it to the parking space.
- Communication Systems: Some systems enable communication between the car and the parking infrastructure, allowing for seamless operations.

Automated parking can be classified into two main types:

- Automated Valet Parking (AVP): In this system, a driver drops the vehicle off at a designated point, and the system takes over to park the car autonomously.
- Automated Parking Garages: These are designed to house robotic systems that autonomously park and retrieve vehicles within a multi-level parking facility.

The primary advantages of automated car parking systems include:

- Space Efficiency: Vehicles can be parked closer together, increasing the number of cars that can fit in a parking lot or garage.
- Reduced Human Effort: The system eliminates the need for drivers to find and maneuver into parking spots.
- Reduced Traffic Congestion: Automated systems help reduce the time spent circling to find an available parking spot.
- Enhanced Safety: Since the vehicle is controlled by sensors and cameras, human error is minimized, leading to fewer accidents in parking areas.

Despite the benefits, challenges like high installation costs, technological integration, and ensuring accessibility for all users remain considerations for the widespread adoption of automated parking systems. However, with advancements in artificial intelligence, robotics, and infrastructure development, automated car parking is steadily moving towards becoming a part of urban transportation systems.

## 1.2 Working Principle

The working principle of automatic car parking (also called self-parking or autonomous parking) involves the integration of advanced technologies, including sensors, control systems and algorithms, to allow a vehicle to park itself with minimal or no input from the driver. The system uses real-time data from the vehicle's surroundings to control its movements and park it in a
designated parking space. Below is a breakdown of the core principles and steps involved in automatic car parking:

Summary of Working Principle:

- Activate parking mode (either automatically or manually by the driver).
- Sensors detect obstacles and parking space.
- Control system processes data, plans the optimal parking path.
- Vehicle steers, accelerates, brakes as necessary to park in the space.
- Automatic adjustments are made to align the car within the space.
- Car parks and stops safely in the designated spot.

Optionally, driver exits and the vehicle parks itself, or the driver can remotely summon the car.

## 1.3 Problem Statement

The Automatic Car Parking System (ACPS) aims to address the challenges of managing limited parking space in urban environments by automating the parking process. This system is designed to efficiently allocate parking spots to incoming vehicles, guide them to available spaces, and manage entry and exit operations without human intervention. Using a combination of sensors, cameras, and real-time data processing, the system tracks the availability of parking spots, automatically directs vehicles to the closest available space, and retrieves them when needed. It optimizes parking space utilization, minimizing congestion and reducing the time spent searching for a spot. Additionally, the system enhances security by controlling access, using technologies like RFID or license plate recognition for vehicle identification. The ACPS offers a more efficient, user-friendly, and secure solution for urban parking problems, making it an ideal option for busy cities with high demand for parking spaces.

## 1.4 Objective of the Project

The objective of an Automatic Car Parking System (ACPS) is to provide an efficient, convenient, and secure solution for managing parking spaces in urban environments. By automating the entire parking process, the system aims to optimize the use of available space, reducing congestion and the time spent searching for parking spots. It enhances the user experience by offering seamless, quick access to parking and retrieval, while also improving security through technologies like RFID or license plate recognition. Additionally, the ACPS reduces operational costs by minimizing the need for manual intervention, and promotes environmental sustainability by decreasing vehicle emissions through quicker parking processes. Overall, the system seeks to address modern parking challenges by offering an intelligent, scalable, and eco-friendly solution that maximizes space utilization and ensures safety for both vehicles and drivers.

## 1.5 Background of the Project

The concept of the Automatic Car Parking System (ACPS) emerged as a response to the growing challenges of urbanization and the increasing demand for efficient parking solutions in crowded cities. As cities became more densely populated, traditional parking methods, which rely on manual parking and the search for vacant spots, became time-consuming and inefficient. This led to issues such as traffic congestion, wasted time, and underutilized parking space. The ACPS was developed to automate the parking process, utilizing advanced technologies like sensors, robotics, and real-time data processing to maximize space usage, reduce human intervention, and optimize the parking experience. Initially, these systems were introduced in high-demand areas such as shopping malls, airports, and office buildings, where space is limited and efficiency is crucial. Over time, with the advancement of automation and artificial intelligence, the ACPS evolved to include automated vehicle movement and sophisticated navigation, further enhancing its effectiveness in busy urban settings. Today, it serves as an innovative solution to modern parking problems, offering an efficient, secure, and environmentally friendly alternative to traditional parking methods.

# Chapter 2
# Components

## 2.1 Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital Input /Output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16MHz ceramic resonator, USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 programmed as a USB-to-serial converter. Changes in Uno R3: 1. Pin out: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the reset pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible with both the board that uses the AVR, which operates with 5v and with the Arduino due that operates with 3.3v. 2. Stronger RESET circuit. 3. ATmega16U2 replace the 8U2. "Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino Boards.

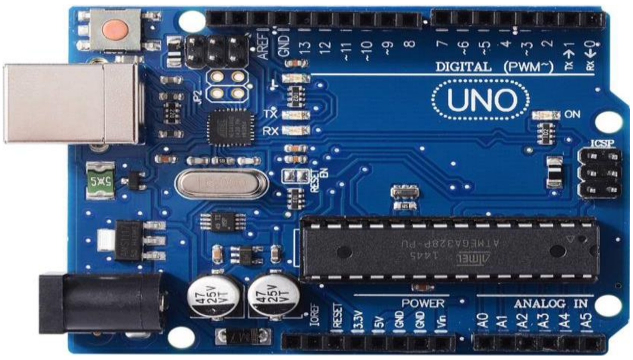


Figure 2.1: Arduino Uno

## 2.2 IR Sensor

An IR (Infrared) sensor is a device that detects infrared radiation (heat) emitted or reflected by objects in its environment. IR sensors are widely used in various applications, including motion detection, proximity sensing and automated systems, due to their ability to detect objects or changes in temperature without physical contact.

Types of IR Sensor:

- Active IR Sensors: These sensors emit infrared light (usually in the form of a beam) and detect the reflection of this light from an object. When the reflected IR light is detected by the sensor, it triggers a response. These are often used in motion detection, proximity sensors, and object counting.
- Passive IR Sensors (PIR): These sensors do not emit any light but instead detect the infrared radiation emitted naturally by objects, especially human bodies. PIR sensors are commonly used in motion detectors for security systems, lighting control, and occupancy sensors.

Components of an IR Sensor:

- Emitter (LED or Laser Diode): It generates infrared light that is either transmitted or reflected back from an object.
- Receiver (Photodiode or Phototransistor): It detects the reflected infrared light or the infrared radiation from an object.
- Optical Lens or Reflector: Helps focus or direct the infrared light emitted or received.
- Signal Processing Circuit: Analyzes the signal from the receiver and triggers an output action based on the sensor’s design.

Applications of IR Sensor:

- Proximity Detection: Used in automatic doors, robotics, and other systems to detect the presence of objects or people nearby.
- Motion Detection: PIR sensors are commonly used in security systems, automatic lighting, and alarms to detect human presence or movement.
- Temperature Measurement: Infrared thermometers and thermal cameras use IR sensors to measure temperature from a distance.
- Obstacle Avoidance: In robotics and automated vehicles, IR sensors help avoid obstacles by detecting nearby objects.

Remote Controls: Many consumer electronics like televisions and air conditioners use IR sensors for receiving signals from remote controls.


Figure 2.2: IR Sensor

## 2.3 Servo Motor

A servo motor is a type of electric motor that is commonly used for precise control of angular position, speed, and acceleration in automation and robotics applications. Unlike standard motors that simply rotate continuously, servo motors can be controlled to rotate to a specific angle and hold that position with high accuracy. This makes them ideal for tasks that require fine, controlled movements, such as in robotics, CNC machines, camera systems, and automated systems.

Components of a Servo Motor System:

- Motor: This is typically a DC motor or an AC motor, and it generates rotational motion.
- Gearbox: In many servo systems, the motor is coupled with a set of gears to reduce the speed and increase the torque of the motor. This allows the motor to provide the necessary force for tasks requiring high precision.
- Control Circuit (Servo Driver): The control circuit processes the input command (e.g., desired position, speed) and sends the appropriate signals to the motor to achieve the requested action.
- Feedback Device: Commonly an encoder or potentiometer, this component monitors the position of the motor shaft and sends real-time data to the control system to ensure the motor is in the correct position.
- Housing/Body: The outer casing of the motor that provides protection and structural integrity.

How Servo Motor Works:

- Input Command: The user sends a control signal, which specifies the desired position (angular displacement) and/or speed for the servo motor.
- Feedback Loop: The servo motor receives this command and begins to rotate. The encoder (or other feedback device) continuously monitors the position of the motor shaft.
- Adjustment: The controller compares the actual position (as reported by the feedback device) to the desired position. If the motor is not in the correct position, the controller sends corrective signals to the motor to adjust its rotation.
- Holding Position: Once the motor reaches the desired position, the controller maintains the position by adjusting the power supplied to the motor, preventing it from drifting away due to external forces or mechanical backlash.

Types of Servo Motor:

- DC Servo Motor: These are simple to control and often used in small-scale applications. They are typically used in systems that require moderate speed and precision.
- AC Servo Motor: These motors are more commonly used in industrial and high-performance applications. AC servo motors generally offer higher efficiency, torque, and speed, and are more suitable for heavy-duty tasks.

➢ Brushless Servo Motor: This type uses permanent magnets instead of brushes to eliminate friction losses, resulting in higher efficiency, longer lifespan, and reduced maintenance compared to brushed motors.

Standard (or Analog) Servo Motor: This type is often used in hobby electronics (such as radio-controlled cars or planes) and typically provides limited angular rotation (usually 90 to 180 degrees). These motors are controlled using PWM (Pulse Width Modulation) signals.


Figure 2.3: Servo Motor

## 2.4 Liquid Crystal LCD I2C

I2C, or Inter Integrated Circuit, is a half-duplex hardware protocol that uses two conductors, one clock (SCL) and one data (SDA) line, to connect two or more devices. One device, designated the master, uses the clock signal to synchronize data transfer to one, or multiple, slave devices at speeds up to 400 Kbps.


Figure 2.4: Liquid Crystal LCD I2C

## 2.5 Breadboard

Breadboards are one of the most fundamental pieces when learning how to build circuits. In this tutorial, you will learn a little bit about what breadboards are, why they are called breadboards, and how to use one. Once you are done you should have a basic understanding of how breadboards work and be able to build a basic circuit on a breadboard.

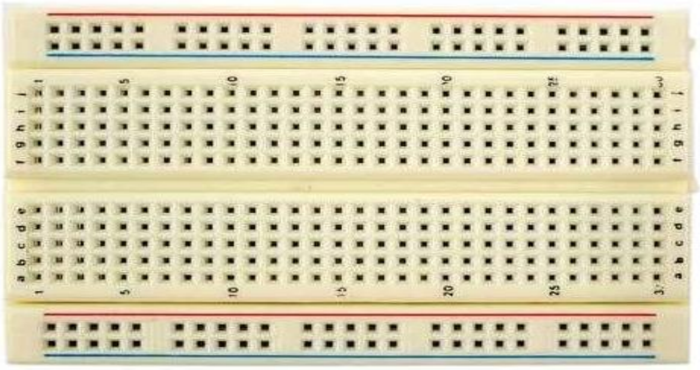

Figure 2.5: Breadboard

## 2.6 Connecting Wire

A jumper wire is a short electrical wire used to make temporary or permanent connections between two points in an electronic circuit. They are typically used in situations where a circuit needs to be connected or completed, but the components or pins are not directly wired together. Jumper wires are commonly used in breadboarding, prototyping, and electronics testing, as well as in embedded systems for connecting various components like sensors, microcontrollers, and actuators.

Figure 2.6: Connecting Wire

# Chapter 3
# Literature Review

## 3.1 Introduction

Automated Car Parking Systems (APS) represent a growing area of interest in urban mobility and intelligent transportation systems. These systems, which use advanced technologies such as Arduino Uno, sensors, and communication systems, aim to address the challenges of urban parking, improve space efficiency, and enhance convenience for users. This literature review presents a summary of key research and developments in the field of automated car parking, with a focus on technologies, system designs, advantages, challenges, and future prospects.

## 3.2 Overview of Automatic Car Parking System

Automatic car parking systems aim to minimize the need for human intervention in parking a vehicle. Unlike traditional parking where the driver maneuvers the car into a spot, APS utilizes advanced robotics and sensing technologies to autonomously park and retrieve vehicles. The fundamental goal of these systems is to optimize space utilization and reduce the time and effort required for parking. Studies by Chien et al. (2008) and Huang et al. (2016) discuss the conceptual framework of APS, highlighting the system's ability to stack cars in tight spaces and operate efficiently in multi-story parking structures.

## 3.3 Technological Components

The functionality of an automated parking system relies heavily on its technological components. According to Liu et al. (2018), these systems integrate several key technologies:

- Sensors: IR sensors is employed to detect obstacles, measure distances, and guide the vehicle accurately into parking spaces. Park et al. (2017) explore how sensor fusion—combining data from multiple sensors—enhances the reliability and accuracy of the system, particularly in complex environments.
- Control Algorithms: Zhou et al. (2019) focus on the control algorithms that dictate the motion and path planning of vehicles in automated parking. These algorithms, often powered by machine learning or optimization techniques, ensure that vehicles are parked in the most efficient manner while avoiding collisions.

Communication Systems: Some APS designs also include Vehicle-to-Infrastructure (V2I) communication, which allows the car to communicate directly with the parking system infrastructure. This can help streamline the parking process and provide real-time updates to users about space availability, as discussed by Gao et al. (2015).

### 3.4 System Design and Configurations

Automated parking systems come in various configurations, and different design approaches aim to optimize efficiency, user experience, and system costs. Wang et al. (2019) outline several common designs:

- Elevator-Based Systems: In these systems, cars are placed on platforms and moved vertically using elevators. Li and Liu (2017) examine the advantages of these systems in high-rise urban areas, where space is limited but vertical movement can optimize parking capacity.
- Shuttle-Based Systems: These involve horizontal and vertical shuttles that transport vehicles to available parking spots. Sun et al. (2018) highlight the benefits of shuttle-based systems in terms of flexibility and ease of integration with existing infrastructure.

Fully Automated Parking Garages: These garages use robotic arms and conveyors to move vehicles into parking spots. A comprehensive study by Li et al. (2015) reviews the technological maturity and economic feasibility of these systems in large-scale applications.

### 3.5 Future Prospects

Looking ahead, the development of APS is likely to be influenced by advances in autonomous driving and electric vehicle technologies. Chen et al. (2021) highlight how the integration of autonomous vehicles into APS can further streamline the parking process by allowing cars to park and retrieve themselves without any human involvement. Additionally, the integration of smart city technologies and 5G communication may enhance the coordination and real-time management of parking systems. Zhang et al. (2020) argue that these technologies will make APS more efficient, scalable, and accessible in urban environments.

Furthermore, eco-friendly solutions such as charging stations for electric vehicles integrated into automated parking garages could become more common, contributing to the sustainability of urban mobility solutions.

# Chapter 4
# Methodology

## 4.1 Introduction

The methodology for designing and implementing an Automated Car Parking (APS) system involves a combination of several key components and technologies, including robotic automation**,** sensors**,** control algorithms and communication systems. This section outlines a general methodology for the development and deployment of an automated car parking system, focusing on system design, hardware implementation, software algorithms, and performance evaluation. The theory of automatic car parking revolves around the use of advanced technologies to enable a vehicle to park itself with minimal or no human intervention. This concept combines elements of automation, sensors, Arduino Uno, servo motor and vehicle control systems.

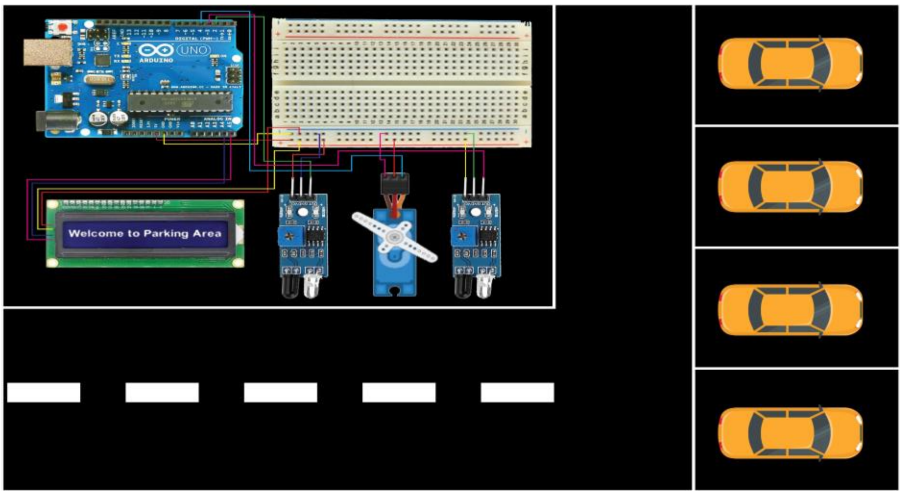


Figure 4.1: Layout of Automatic Car Parking System

## 4.2 Control System

Once the sensors collect data, the car's onboard control system processes this information and makes real-time decisions about how to move the vehicle. The key components include:

- Steering Control: Automatic steering adjustments are made based on sensor inputs to guide the car into the parking space.
- Throttle and Braking: Automatic control of the car’s acceleration and braking ensures the car enters the parking space smoothly and safely.

Transmission Control: The vehicle’s transmission is also controlled automatically to shift between forward and reverse gears as needed.

### 4.3 Software and Algorithms

The algorithm or software system interprets the data from the sensors and makes decisions based on pre-programmed logic.

This includes:

- Path Planning Algorithms: These algorithms determine the optimal path for the vehicle to follow to park itself. They take into account the size of the parking space, the surrounding environment, and any obstacles.
- Machine Learning: In more advanced systems, machine learning models can be used to improve the system’s ability to predict obstacles, optimize parking strategies, and adapt to various parking environments.

Types of Automatic Parking:

- Parallel Parking: The vehicle parks parallel to a curb, typically between two other vehicles.
- Perpendicular Parking: The vehicle parks head-in or back-in into a space, aligned with the parking lot rows.
- Angle Parking: The vehicle parks at a specified angle to the curb or parking lot lines.
- Valet Parking: Advanced systems allow the driver to exit the vehicle and have the car autonomously park itself. The driver can summon the car from its parking spot when needed.

Communication and Integration:

- Vehicle-to-Vehicle (V2V): In some systems, the vehicle may communicate with other nearby vehicles to avoid collisions and optimize parking.
- Vehicle-to-Infrastructure (V2I): Communication between the vehicle and infrastructure, such as smart parking systems that can direct the car to an available space, is also increasingly common.
- Cloud-based Systems: Some systems use cloud computing to store parking data, share information between cars, and improve the parking process over time.

Types of Automatic Parking Systems:

- Autonomous Parking Assistance: The driver starts the parking process but the car completes it autonomously. For example, the driver may guide the car to a nearby space and then the system takes over the steering and braking.
- Fully Autonomous Parking (Self-parking): The vehicle autonomously finds a parking spot and parks itself without the driver needing to assist at all. In some cases, the car can even return to the owner’s location upon request.

Advantages of Automatic Parking:

- Space Efficiency: Automatic systems can park cars more closely together, increasing the number of vehicles that can fit in a parking lot or garage.
- Time-Saving: It can reduce the time spent searching for parking, as the system can autonomously park or retrieve the vehicle.

- ➢ Safety: Automated parking can reduce accidents caused by human error during parking, such as hitting other vehicles or pedestrians.
- ➢ Convenience: For drivers, it removes the stress and complexity of parking, especially in tight or congested spaces.

Challenges and Future Directions:

- ➢ Technology and Sensor Limitations: Despite advancements, sensors may still struggle in certain conditions, like fog, rain, or night time.
- ➢ Regulatory and Legal Issues: Autonomous parking systems must meet safety standards and local laws, which are still evolving.

Infrastructure: Parking spaces and garages may need to be redesigned to accommodate these systems, such as adding more precise sensors or creating better space management protocols.

### 4.4 Block Diagram

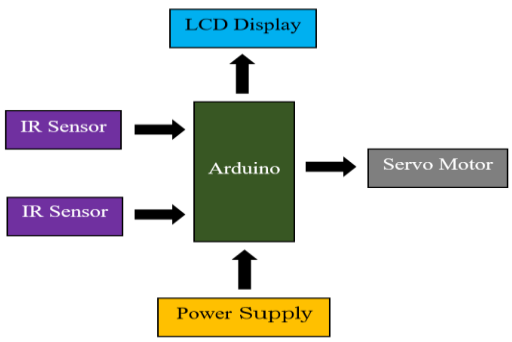


Figure 4.4: Block Diagram of Automatic Car Parking System

### 4.5 Circuit Diagram

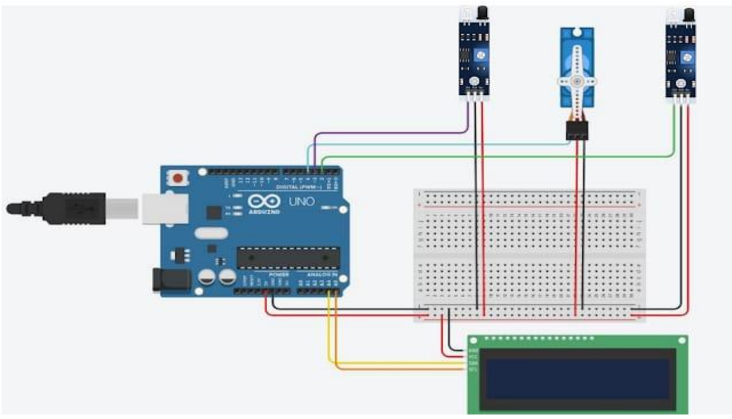


Figure 4.5: Circuit Diagram of Automatic Car Parking System

## 4.6 Overview of the Parking Slot Allocation Process

The Automatic Car Parking Slot Allocation Process is designed to efficiently manage available parking spaces in an automated system, optimizing space usage and minimizing human intervention. Here's a breakdown of how the process typically works:

Vehicle Entry Detection

- Process: As a vehicle approaches the parking lot entrance, the system detects the vehicle using sensors (like IR sensors).
- Goal: Identify the vehicle's size (compact, medium, large) and ensure its eligibility for available slots.

Available Slot Identification

- Process: The system scans the parking area for available slots using sensors or cameras.
- Slot Criteria: The system checks for various criteria such as slot size, availability, and accessibility (some slots may be reserved for specific vehicle types or sizes).
- Goal: Ensure the vehicle is directed to a suitable slot based on its size and the system's capacity.

Vehicle Guidance

- Process: Once a suitable slot is selected, the system provides guidance to the vehicle (using visual indicators, LED lights, or a guided path).
- Goal: Guide the vehicle precisely to the parking space with minimal effort, avoiding collisions with other cars or obstacles.

End of Parking Session

- Process: The system remains active, waiting for the next vehicle to arrive and the next parking process to begin.
- Goal: Maintain smooth operations and ensure the system is ready for the next vehicle.

## 4.7 Flowchart of the Automatic Parking Management Process

Here's a simple flowchart for the Automatic Parking Management Process

Start

System Initialization: The system starts when the parking facility is powered up and ready to operate.

Vehicle Entry Process:

i. Vehicle Approaches Entrance

ii. Vehicle Size Detection
iii. Available Slot Check
iv. Slot Assignment
v. Guided to Parking Slot
vi. Vehicle Parks in Slot
vii. Slot Occupancy Update
viii. Payment Process (if applicable)

Vehicle Retrieval Process:

i. Vehicle Retrieval Request
ii. Vehicle Slot Identification
iii. Path Clear Check
iv. Vehicle Retrieval
v. Vehicle Exit
vi. Payment Settlement (if not done previously)

End

System Ready for Next Vehicle: After vehicle retrieval or parking, the system is ready for the next process to begin.

Simplified Visual Flowchart:

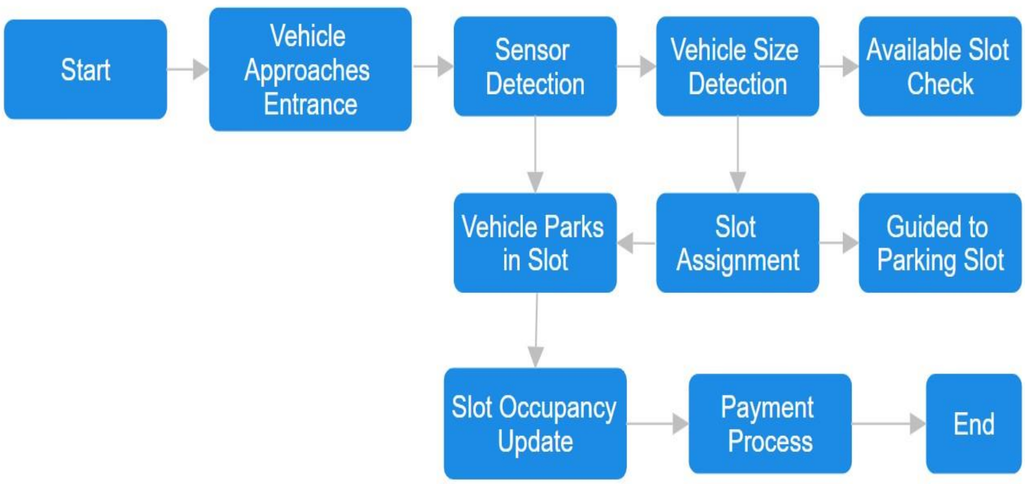


Figure 4.7: Flowchart of the Automatic Parking Management Process

## 4.8 Vehicle Entry and Parking Process in the System

The Vehicle Entry and Parking Process in an automatic car parking system is designed to handle the vehicle from the moment it enters the parking area until it is securely parked in an available slot. Below is a step-by-step breakdown of this process:

- Vehicle Approaches Entrance
- Vehicle Identification & Size Detection
- Slot Availability Check
- Slot Assignment
- Vehicle Guidance
- Vehicle Parks in Slot
- Slot Occupancy Update
- Payment Process (if applicable)
- End of Parking Process

Visual Flow of the Process:

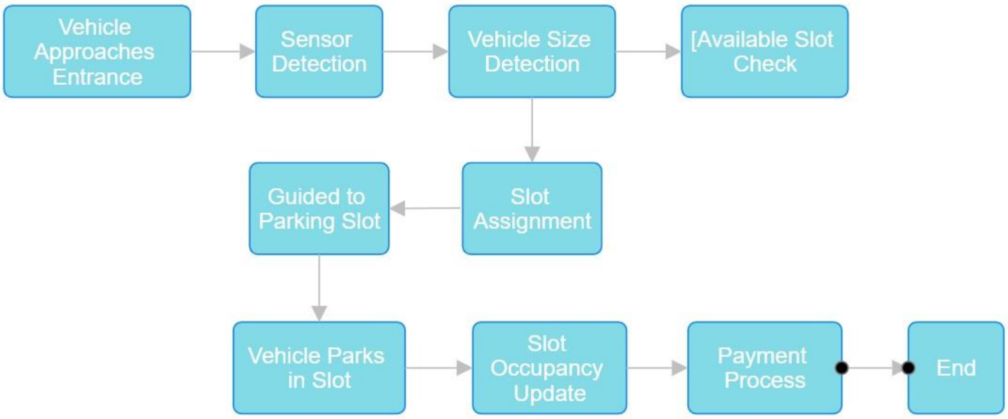


Figure 4.8: Flowchart of Vehicle Entry and Parking Process in the System

# Chapter 5
# Results and Discussion

## 5.1 Introduction

The implementation and deployment of Automated Car Parking Systems (APS) have shown promising results in terms of operational efficiency, space utilization, user convenience, and environmental benefits. However, there are still several challenges to address in terms of cost, scalability, and system robustness. This section discusses the key findings from the literature and experimental results, highlighting the performance, advantages, limitations, and future directions for APS.

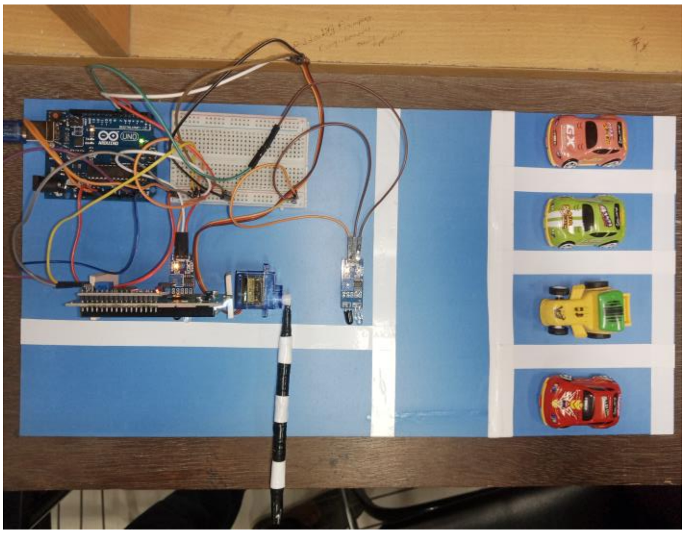

Figure 5.1: On Stage System Automatic Car Parking System

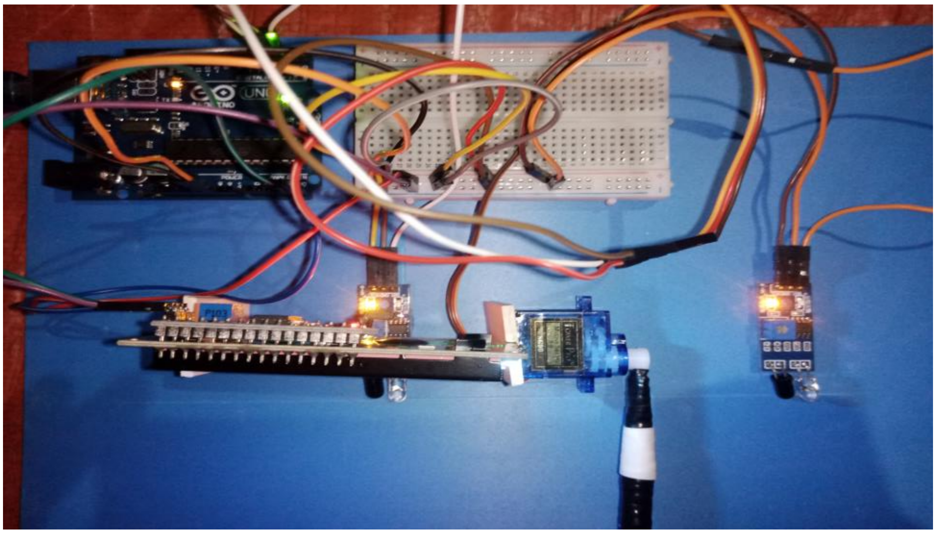

Figure 5.1.1: Overview of Automatic Car Parking System

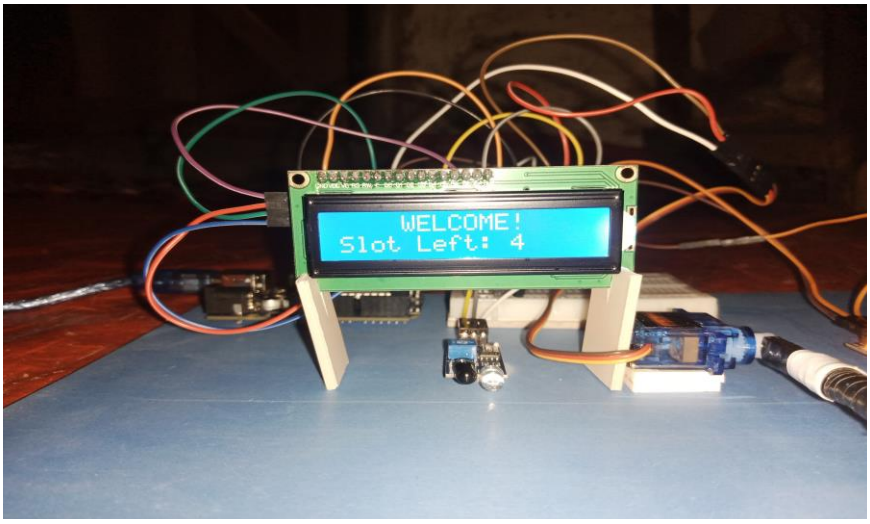


Figure 5.1.2: Parking Entry Display

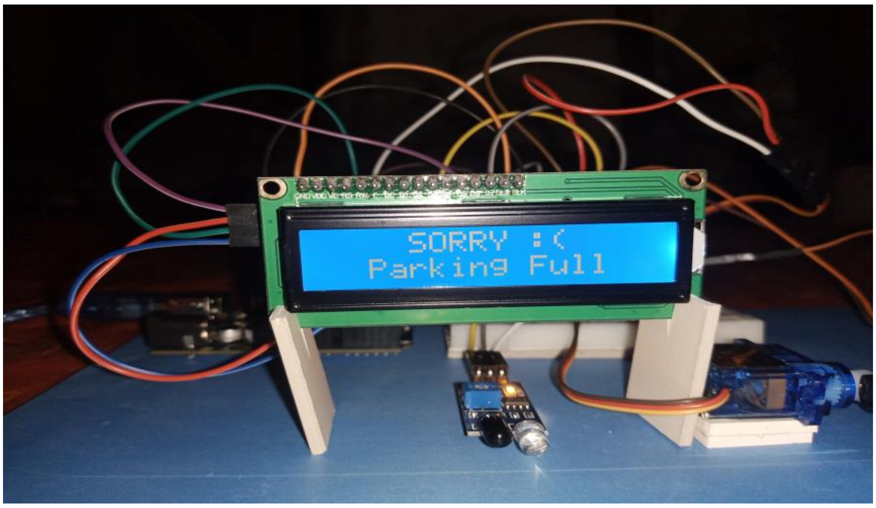


Figure 5.1.3: Parking Full Alert

## 5.2 Space Utilization

One of the key advantages of APS is its ability to optimize parking space utilization. Research studies and real-world implementations have demonstrated that APS can significantly increase the number of vehicles that can be parked in a given area compared to traditional parking systems. For example, Mohan et al. (2018) show that APS can achieve up to 60% higher parking density compared to conventional parking garages. This is due to the elimination of the need for wide aisles and human maneuvering space, as robotic systems can park vehicles more compactly.

- Experimental Results: In a case study of a multi-story automated parking garage in Singapore, it was observed that an automated system allowed for up to 30% more vehicles to be parked in the same floor area compared to manual parking.

- Discussion: This increase in space utilization is particularly beneficial in high-density urban areas where land is scarce and expensive. It provides a viable solution to the growing demand for parking spaces in cities with limited real estate.

### 5.3 Benefits of Automatic Car Parking

The primary benefits of APS include:

- Space Efficiency: APS can increase the number of vehicles that can be parked in a given area by eliminating the need for wide aisles and allowing cars to be parked closer together. Mohan et al. (2018) demonstrate that automated systems can increase parking density by up to 60% compared to conventional parking garages.
- Time Efficiency: Automated parking systems reduce the time spent searching for a parking spot. Ahmed et al. (2017) show that AVP systems can reduce parking time by approximately 40-50%, improving overall traffic flow in busy urban areas.
- Environmental Impact: Automated parking systems can help reduce fuel consumption by optimizing vehicle movement within parking structures, thereby minimizing the time spent idling. Studies by Zhao et al. (2020) suggest that APS can contribute to reducing $CO_2$ emissions in dense urban environments.

Convenience: Users do not need to manually park their vehicles, and the car is parked by the system, which can be particularly beneficial in large, multi-level parking facilities. This feature enhances the user experience by reducing the stress associated with parking in crowded environments.

### 5.4 Challenges and Limitations

Despite the numerous benefits, APS faces several challenges:

- High Initial Cost: The installation of automated parking systems can be costly due to the need for specialized infrastructure, sensors, robotics, and software. Hwang et al. (2020) note that the cost of setting up automated parking is a major barrier to widespread adoption, especially in low-density areas.
- Technical Complexity: The integration of complex algorithms, robotics, and sensors requires sophisticated design and maintenance. Zhou et al. (2019) discuss the challenges in developing reliable systems that can handle a wide variety of vehicles in different parking scenarios.
- Scalability: Implementing APS in large-scale, multi-story parking garages can be difficult due to the complexity of managing robotic systems and ensuring smooth operation in crowded settings. Zhang et al. (2018) explore the scalability issues related to robotic movement and the optimization of parking flow in large systems.

- Public Acceptance: Some users may be hesitant to adopt automated parking due to concerns about safety, security, and reliability. Miller et al. (2017) address these

concerns, pointing out the need for clear communication and trust-building measures to encourage wider adoption.

### 5.5 Parking Time Reduction

APS systems are designed to minimize the time required for parking and retrieving vehicles. In traditional parking systems, drivers often spend significant time searching for available spaces. APS, by contrast, automates this process, reducing the time spent on finding and maneuvering into parking spots.

- Experimental Results: A study by Zhao et al. (2020) showed that automated parking systems could reduce the parking time by 40-50% compared to conventional parking. Similarly, Huang et al. (2016) found that users of APS experienced a 20% reduction in time spent retrieving their vehicles compared to traditional parking garages.
- Discussion: This time efficiency not only enhances user experience but also contributes to reducing traffic congestion in busy urban areas, where drivers spend significant amounts of time circling parking lots in search of space.

Automated car parking systems can contribute to environmental sustainability by reducing carbon emissions and improving energy efficiency in urban environments.

### 5.6 Reduction in $CO_2$ Emissions

By reducing the time spent searching for parking, APS helps decrease vehicle idling, which in turn lowers fuel consumption and reduces carbon emissions. Additionally, the automated nature of the system allows for more efficient management of parking space allocation, minimizing the overall distance vehicles travel within parking facilities.

- Experimental Results: A simulation study conducted by Gao et al. (2015) estimated that implementing APS in a medium-sized urban area could reduce annual $CO_2$ emissions by 20%, mainly due to the reduction in fuel consumption from less time spent searching for parking.
- Discussion: Given the global push for sustainability and green technologies, APS can play an important role in the transition to more environmentally friendly urban transport systems. It offers a promising solution for cities aiming to reduce their carbon footprint, especially when integrated with electric vehicle (EV) charging infrastructure.

## 5.7 Energy Consumption

Automated systems are often considered to be more energy-efficient than traditional parking facilities, where vehicles often move in and out of parking spaces inefficiently due to the need for human drivers. The integration of smart algorithms and sensor technologies enables APS to optimize vehicle movement, reducing unnecessary energy consumption.

- Experimental Results: According to a study by Li et al. (2017), automated parking systems showed a 10-15% reduction in energy consumption compared to conventional parking operations, due to the more direct movement of vehicles and the elimination of unnecessary vehicle movements.
- Discussion: This reduction in energy consumption aligns well with the global emphasis on energy efficiency in urban planning. As APS systems continue to evolve, they could integrate further energy-saving technologies, including regenerative braking and optimized power management for electric vehicles.

One of the main reasons for adopting APS is the convenience it offers to users, particularly in crowded urban environments. The ability to drop off a vehicle and have it autonomously parked can significantly enhance the user experience.

## 5.8 Ease of Use

APS systems are designed to be user-friendly, allowing drivers to simply drop off their car at an entrance point and leave the system to handle the parking process. Users can retrieve their vehicles in a similar fashion, often using a mobile app or a smart interface to request their car.

- Experimental Results: In a survey conducted by Park et al. (2017) on user satisfaction, 85% of users reported high satisfaction with the ease of use and convenience provided by APS, particularly in terms of not having to navigate through crowded parking lots.
- Discussion: APS systems eliminate the stress of parking in busy areas and offer significant convenience for drivers, especially in urban environments where finding parking can often be frustrating and time-consuming.

## 5.9 Safety

The automated nature of APS improves safety by reducing human error, which is a common cause of accidents in traditional parking lots. Automated systems use sensors and cameras to detect obstacles, ensuring that vehicles are parked with minimal risk of collision.

- Experimental Results: Safety studies from Shin et al. (2020) indicate that automated systems reduce the occurrence of parking-related accidents by 30-40% compared to manual parking systems, primarily due to the real-time monitoring of obstacles and the elimination of human judgment errors.

- Discussion: The improved safety features not only benefit users but also reduce the risk of damage to vehicles, which in turn can lead to lower insurance costs and fewer claims.

Despite the promising results of APS, several challenges must be addressed for the wider adoption of automated parking systems.

### 5.10 High Initial Cost

One of the major barriers to implementing APS is the high initial cost of infrastructure, including sensors, robotics, control systems, and construction of specialized parking facilities.

- Experimental Results: According to Li and Liu (2017), the initial cost of installing an automated parking system can be two to three times higher than traditional parking systems, primarily due to the technology and infrastructure requirements.
- Discussion: While the long-term benefits of APS, such as increased space utilization and reduced operational costs, may offset the initial investment, the high upfront costs remain a significant challenge, particularly for smaller cities or private developers.

### 5.11 Scalability

While APS works well in smaller or medium-sized parking facilities, scaling up to larger, multi-story parking structures presents challenges. Issues such as robotic performance, coordination of multiple vehicles, and space optimization need to be carefully addressed.

- Discussion: Scalability concerns relate to both the technical capacity of robotic systems and the economic feasibility of larger systems. Future developments may focus on improving the flexibility and modularity of APS to handle different types of parking environments and demands.

### 5.12 User Trust and Acceptance

Another barrier to widespread adoption of APS is user trust. Some drivers may be reluctant to leave their vehicles in the hands of an automated system, particularly in terms of security, reliability, and system malfunctions.

- Discussion: Public education and demonstrations of system safety and reliability will be key to overcoming this challenge. Clear communication of the benefits of APS, as well as the implementation of robust security protocols, will help build confidence in the technology.

The future of APS is likely to involve the integration of autonomous vehicles, smart city technologies, and 5G communication systems. Key areas for future development include:
Integration with Autonomous Vehicles (AVs): As AV technology matures, APS could become fully autonomous, allowing vehicles to park and retrieve themselves without any human intervention.

- Smart Parking: APS systems can be integrated with smart city infrastructure to provide real-time data on parking space availability, reducing congestion and improving traffic flow.
- Sustainability: Further innovations in energy efficiency, including integration with electric vehicle charging stations, will enhance the environmental benefits of APS.

# Chapter 6
# Conclusions

## 6.1 Space Optimization and Efficiency

One of the most significant advantages of APS is their ability to maximize space utilization. By removing the need for wide aisles and human maneuvering space, APS systems can park vehicles in a much denser configuration than conventional parking facilities. This increase in parking capacity is particularly valuable in urban areas with limited land. Studies have shown that APS can increase parking space efficiency by up to 60% compared to traditional
parking garages. Furthermore, the systems can handle larger volumes of vehicles with optimized traffic flow, improving overall parking efficiency.

## 6.2 Environmental Benefits

APS contribute to environmental sustainability by reducing vehicle idling time, which in turn decreases fuel consumption and carbon emissions. With less time spent driving around parking lots looking for spaces, vehicles spend less time in motion and consume less energy. Additionally, as more cities focus on electric vehicle (EV) adoption, APS can seamlessly integrate EV charging stations into the system, further promoting green mobility.

## 6.3 Safety and User Convenience

Safety is a key benefit of APS, as these systems significantly reduce the risk of accidents and collisions that can occur in conventional parking lots due to human error. By utilizing sensors, cameras, and advanced control systems, APS provide enhanced collision detection and real-time feedback, ensuring that vehicles are parked without incidents. Furthermore, the user convenience provided by APS cannot be overstated. Whether through Automated Valet Parking or Automated Parking Garages, users enjoy a smoother, faster, and hassle-free parking experience, with fewer chances of damage to their vehicles.

## 6.4 Conclusions

Automated Car Parking Systems (APS) represent a transformative solution for managing urban parking challenges, offering significant benefits in terms of space utilization, efficiency, safety, and user convenience. As urbanization increases and the demand for parking space grows, APS are becoming an essential tool in optimizing parking management, particularly in densely populated cities where traditional parking solutions are often insufficient. Below are the key conclusions derived from the development, implementation, and evaluation of APS.

# References


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- Hwang, S., et al. (2020). "Economic and environmental challenges of automated car parking systems." *Urban Studies*.
- Liu, H., et al. (2018). "A review of sensor technologies for automated car parking." *Sensors*.
- Miller, L., et al. (2017). "Public perceptions of automated parking technology." *Transportation Research Part A*.

# Appendix

```
#include <Wire.h>

#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x3F,16,2);

#include <Servo.h>


Servo myservo;


int IR1 = 2;

int IR2 = 3;


int Slot = 4;           //Total number of parking Slots


int flag1 = 0;

int flag2 = 0;


void setup() {

  Serial.begin(9600);

    lcd.init(); //initialize the lcd

    lcd.backlight(); //open the backlight



pinMode(IR1, INPUT);

pinMode(IR2, INPUT);
```

```
myservo.attach(9);
myservo.write(100);

lcd.setCursor (0,0);
lcd.print("     ARDUINO    ");
lcd.setCursor (0,1);
lcd.print(" PARKING SYSTEM ");
delay (2000);
lcd.clear();
}

void loop(){

if(digitalRead (IR1) == LOW && flag1==0){
if(Slot>0){flag1=1;
if(flag2==0){myservo.write(0); Slot = Slot-1;}
}else{
lcd.setCursor (0,0);
lcd.print("    SORRY :(    ");
lcd.setCursor (0,1);
lcd.print("  Parking Full  ");
delay (3000);
lcd.clear();
}
```

```
}

if(digitalRead (IR2) == LOW && flag2==0){flag2=1;
if(flag1==0){myservo.write(0); Slot = Slot+1;}
}

if(flag1==1 && flag2==1){
delay (1000);
myservo.write(100);
flag1=0, flag2=0;
}

lcd.setCursor (0,0);
lcd.print("    WELCOME!    ");
lcd.setCursor (0,1);
lcd.print("Slot Left: ");
lcd.print(Slot);
}
```