Computer Vision-Based Parking Management System

Capstone Project Report

FINAL EVALUATION

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ABSTRACT

The rapid development of modern cities has created an increasing issue in efficiently managing parking spots while assuring security. This abstract offers a revolutionary solution - a Computer Vision-Based Parking Management System - to revolutionize parking management by incorporating computer vision techniques. The system's primary goal is to use real-time data and cutting-edge technology to automate the parking process, improve parking efficiency, and improve overall parking security.

The suggested system employs computer vision techniques to detect vehicles entering and exiting a parking space. The data collected provides real-time updates on parking spot availability and precise vehicle arrival and departure times. The system's uniqueness stems from its capacity to improve both user experience and security at the same time, solving significant pain points in traditional parking management.

Furthermore, the system includes robust security features to prevent unauthorized access, lowering the chance of theft and other security concerns. The system acts as a proactive deterrence against prospective security breaches by detecting and responding to unauthorized access as soon as it is detected.

The Computer Vision-Based Parking Management System's primary purpose is threefold: to automate the parking process, maximize parking space use, and augment parking security. Drivers can efficiently identify parking spots thanks to real-time availability updates, decreasing congestion and search times. Accurate vehicle arrival and departure times help to better record-keeping, fewer disagreements, and increased openness.

From the standpoint of parking lot owners, the system provides numerous advantages. The technology maximizes income generation possibilities by maximizing parking space use and providing accurate occupancy statistics. Furthermore, integrating security measures ensures asset protection, lowering operational losses due to theft and unauthorized access.

Subsequently, this abstract sheds light on a pioneering effort to change parking management by combining computer vision technology. The system's capacity to automate, improve efficiency, and boost security offers great promise for urban planners and citizens alike. The Computer Vision-Based Parking Management System strives to make urban parking smarter, safer, and more user-centric by tackling the difficulties of parking congestion, inefficient space usage, and security risks.

DECLARATION

We hereby declare that the design principles and working prototype model of our project is an authentic record of our work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Ajay Kumar during the 7th semester (August – December 2023).

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Lastly, we thank our families for their unyielding love and encouragement. They always wanted the best for us and we admire their determination and sacrifice.

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1. Introduction

1.1 Project Overview

The Computer Vision-Based Parking Management System aims to revolutionize the parking experience by automating the entire parking management process. The system can detect vehicles entering and exiting a parking area by leveraging advanced computer vision techniques. This information will then provide real-time updates on parking spot availability and the precise time of vehicle arrival and departure. The system will also incorporate robust security measures to prevent unauthorized access, thereby enhancing overall parking security.

The primary objectives of the system are as follows:

1. **Automation of Parking Process**: The system will eliminate the need for manual intervention in parking management. Vehicles entering and exiting the parking area will be seamlessly detected, reducing congestion and enhancing user experience.
2. **Real-time Parking Information**: By utilizing computer vision, the system will provide real-time updates to drivers about available parking spots, enabling them to make informed decisions quickly.
3. **Enhanced Parking Efficiency**: Automation and real-time information will lead to optimized parking space utilization, minimizing idle time and congestion within the parking facility.
4. **Precise Arrival and Departure Times**: The system will accurately record the times at which vehicles enter and exit the parking area, improving record-keeping and reducing disputes.
5. **Unauthorized Access Prevention**: Robust security measures will be implemented to detect and respond to unauthorized access attempts, reducing the risk of theft and other security concerns.

The system architecture comprises several key components:

1. **Camera Network**: An array of strategically placed cameras will capture video feeds of the parking area. These feeds will be processed using computer vision algorithms.

2. **Vehicle Detection**: Computer vision algorithms will be employed to identify and track vehicles entering and exiting the parking area. This involves license plate recognition and vehicle type identification.
3. **Data Processing**: The captured data will be processed in real-time to determine parking spot availability and calculate vehicle dwell times.
4. **User Interface**: A user-friendly interface, accessible through mobile apps and web platforms, will display real-time parking availability, spot locations, and estimated arrival times.
5. **Security System**: In case of unauthorized access attempts, the system will trigger alerts, notify security personnel, and may even initiate preventative actions like automated barrier closure.

The Computer Vision-Based Parking Management System offers a multitude of benefits to the user:

1. **Parking Lot Owners**:
    i) Enhanced Customer Experience: Real-time updates on parking availability improve customer satisfaction.
    ii) Increased Revenue: Optimized parking space utilization leads to higher revenue generation.
    iii) Data-Driven Insights: Access to data on parking patterns facilitates informed decision-making.
2. **Drivers**:
    i) Time Savings: Quick access to real-time parking information minimizes search time.
    ii) Convenience: Precise arrival and departure times aid in planning.
    iii) Reduced Stress: Automation reduces congestion and enhances the overall parking experience.

Project Implementation:

1. Camera Installation: Cameras will be strategically installed to cover entry and exit points, as well as parking spots.

2. Data Collection: Video feeds from cameras will be processed by computer vision algorithms to detect vehicles and gather relevant information.
3. Real-time Updates: Processed data will be used to update the parking availability status and estimated arrival times in real-time.
4. Security Integration: Unauthorized access detection mechanisms will be integrated, including license plate recognition for white/blacklisting vehicles.
5. User Interface Development: Intuitive mobile apps and web platforms will be developed to provide users with access to parking information.

1.2 Need Analysis

The need for computer vision-based approaches is clear, as they offer a range of benefits in terms of automation, analysis, accuracy, and safety. By harnessing the power of computer vision, we can develop innovative solutions to some of the most pressing challenges we face today, from improving parking management to increasing crop yields and enhancing food security. As the technology continues to evolve, we can expect to see even more applications of computer vision in the years to come.

While it is still a good choice for places with a smaller parking capacity, the management of a parking area with a capacity of hundreds is a Herculean task with traditional means and methods. Also the fact that unique fields of uses have unique use cases that they would want implemented. After some research, numerous problems that are associated with the traditional parking management system are as follows -

- **Security Lapses**: A computer vision based parking management system can help improve the security of the parking lot. By detecting the number plates of entering vehicles, the system can determine if the vehicle is authorized to park in the designated parking area, and maintain an entry and exit log to track all vehicles coming in and out. Also, the use of camera will provide a round-the-clock surveillance system.
- **Inefficient Entry and Exit System**: Manual entry and exit systems can lead to long queues and delays. An automated entry and exit system that uses number plate recognition can help to reduce delays and improve the overall efficiency of the parking process.

- **Labour Costs**: Manual parking spot management and entry and exit systems can require a lot of manual labour, resulting in high labour costs for parking lot owners. An automated system can help to reduce these costs and improve the overall efficiency of the parking lot.
- **Poor Parking Experience**: Drivers often find it difficult to find vacant parking spots in crowded parking areas, leading to frustration and inconvenience. A system that can detect vacant parking spots and display them to drivers can help to improve the parking experience and reduce user frustration.

1.3 Research Gaps

Identifying research gaps is crucial for refining the scope of our project and contributing to the existing body of knowledge. Here are five potential research gaps in the context of the Computer Vision-Based Parking Management System:

1. **Real-time Vehicle Tracking in Dynamic Environments**:

   Research Gap: While real-time vehicle tracking is essential for parking management, existing solutions may need help accurately tracking vehicles in dynamic environments with varying lighting conditions, occlusions, and complex movement patterns.

   Explanation: Real-time tracking of vehicles in a parking area can be a challenging task due to multiple factors, such as changing lighting conditions, blind spots in visions caused by other vehicles, and complex movement patterns of vehicles and pedestrians. Addressing these challenges requires robust computer vision algorithms that can adapt to dynamic environments and handle occlusions effectively.

   Reference: *Khan, S. et al. [1] (2019). A review of vehicle detection and tracking methods in video surveillance. EURASIP Journal on Image and Video Processing, 2019(1), 1-25*.

2. **Privacy Concerns in License Plate Recognition**

Research Gap: Privacy concerns related to license plate recognition (LPR) and the storage of vehicle-related data need to be addressed to ensure the ethical implementation of the parking management system.

Explanation: License plate recognition plays a crucial role in vehicle identification and security enforcement. However, the collection and storage of license plate data raise privacy concerns, especially when considering the potential for unauthorized access or misuse of sensitive information. Research is needed to develop privacy-preserving LPR methods and policies that balance security with privacy rights.

Reference: *Wahab, A. W. A. et al. [2] (2020). License Plate Recognition System: A Review. In 2020 IEEE 5th International Conference on Smart City-SocialCom-SustainCom (SmartCity360) (pp. 205-211).*

3. **Scalability and Resource Efficiency in Large Parking Lots**

Research Gap: Existing systems lack the scalability and resource efficiency needed to manage parking in large and densely populated parking lots effectively.

Explanation: Scalability is a critical factor for parking management systems, especially in large parking lots or urban areas. These systems need to handle many vehicles and provide real-time updates without compromising on resource efficiency. Research is required to optimize algorithms and system architecture for scalability and resource management.

Reference*: Perera, C. et al. [3] (2018). Scalability and resource efficiency for smart city applications. IEEE Communications Magazine, 56(8), 84-89.*

4. **Integration of Multi-Sensor Data Fusion**

Research Gap: Integrating data from multiple sensors, such as cameras and other IoT sensors to enhance accuracy and robustness in parking spot detection and vehicle tracking remains an open research area.

Explanation: A multi-sensor approach can improve the accuracy and reliability of parking spot detection and vehicle tracking, more generally object detection. Integrating data from cameras, IoT senors and other sources can provide a more

comprehensive understanding of the parking environment. Research is needed to continue the development of effective methods for fusing data from various sources and sensors to enhance system performance.

Reference: *Mainetti, Luca, et al. [4] "Integration of RFID and WSN technologies in a Smart Parking System." 2014 22nd international conference on software, telecommunications and computer networks (SoftCOM). IEEE, 2014.*

5. **User-Centred Design and User Experience**

   Research Gap: Limited attention might have been given to the user-centred design aspects of the user interface and the overall user experience, potentially leading to usability issues.

   Explanation: A user-friendly interface is crucial for the success of a parking management system. User-Centred design principles need to be applied to ensure that the interface is intuitive, easy to navigate, and provides relevant information to users. Research is needed to study user preferences and behaviour to optimize the user experience.

   Reference: *Hassenzahl M. et al. [5] (2006). User experience—a research agenda. Behaviour & Information Technology, 25(2), 91-97.*

1.4 Problem Definition and Scope

Parking management is a significant challenge for public and private organizations, particularly in congested areas with scarce parking spots. Locating empty parking spaces manually is a time consuming and frustrating task that consumes time and resources. Furthermore, in crowded parking lots, it is often challenging to navigate and locate available parking spaces, causing frustration to drivers and leading to inefficient use of parking space. Therefore, there is a need for a reliable and automated parking management system that can quickly detect vacant parking spaces and assist drivers in locating them efficiently.

The proposed solution is a computer vision-based parking management system that uses machine learning to detect available parking spaces. This system aims to provide drivers with real-time information on the availability of parking spots, thereby

improving the overall parking experience and reducing parking time. Additionally, the system will allow parking lot managers to optimize parking lot usage, minimize congestion, and improve revenue generation by maximizing the utilization of available parking spaces. Thus, the problem statement is to design and develop a computer vision-based parking management system that can detect vacant parking spaces using machine learning. It will assist drivers in finding parking spaces quickly and effectively while keeping track of the entry of authorized and unauthorized vehicles in the parking space.

The scope of the Computer Vision-Based Parking Management System encompasses the development of a comprehensive solution to revolutionize parking management processes. The system will leverage computer vision techniques and machine learning to automate the detection of available parking spaces, record entry and exit times accurately, and enhance security measures.

Key Components within the scope of the project include:

1. **Computer Vision-Based Detection**: Developing an object detection model using machine learning algorithms to identify vacant and occupied parking spaces in real-time through camera feeds.
2. **Entry and Exit Time Recording**: Implementing a system to accurately record the entry time of vehicles using license plate recognition (OCR) technology, which will also distinguish between authorized and unauthorized vehicles.
3. **Real-Time Information Dissemination**: Creating user interfaces, such as mobile apps and web platforms, to provide real-time information to drivers about parking spot availability, locations, and estimated arrival times.
4. **Security Measures**: Integrating security features by leveraging license plate recognition for detecting unauthorized access attempts and triggering security alerts.
5. **Database and Reporting**: Designing a database to store vehicle entry data, including license plate numbers, entry times, and vehicle types, and providing parking lot managers with tools for monitoring space utilization and generating reports.

6. **User Experience Enhancement**: Developing intuitive and user-friendly interfaces for drivers to facilitate easy navigation to available parking spots and provide a positive overall experience.
7. **Testing and Optimization**: Rigorous testing and fine-tuning of the system's algorithms and components to ensure accuracy, efficiency, and reliability in various scenarios.
8. **Deployment and Integration**: Deploying the system in a real parking area, ensuring proper hardware setup, connectivity, and integration with existing infrastructure.

1.5 Assumptions and Constraints

S.No	Assumptions
1.	Let us assume that the cameras used for parking spot detection will be stably mounted and will provide consistent and clear views of the parking area without significant movement or distortion. Under this assumption, we have designed the system to take the parking's live feed for Video processing frame-by-frame.
2.	It is assumed that the Computer Vision algorithms and models for license plate recognition, optical character identification and vacant spot detection are significantly accurate. The system's effectiveness relies on the precision of these algorithms, which may be influenced by environmental factors like lighting conditions and weather conditions.
3.	The project assumes that the parking layout within the designated area remains relatively consistent without frequent changes in parking spot configurations
4.	It is assumed for the system that vehicles will move at reasonable speeds upon entering the parking area to allow sufficient time for accurate detection and data recording. The system also assumes that vehicles will be parked in

	standard orientations, allowing clear visibility of license plates for accurate recognition.

Table 1: Table of Assumptions

S.No	Constraints
1.	The developed system can be constrained under the budget provided for such an application. Components such as cameras and computing resources may be impacted. Balancing all functions with the cost restrictions is a major constraint.
2.	Unruly weather conditions and lighting condition are also a constraint for the system's performance. The system should be resilient to environmental challenges to ensure consistent performance.
3.	Privacy regulations and concerns related to storage of license plate data is a significant constraint. Following privacy laws is important for legal and ethical considerations of the system.
4.	Regular maintenance and updates are required for cameras, algorithms, and hardware components involved in the system. Neglecting maintenance could lead to system degradation over a period of time.

Table 2: Table of Constraints

1.6 Standards:

1. Image Processing Standards:

- To ensure reproducibility, all de-noising and segmentation algorithms should be implemented using well-known libraries and frameworks.
- All photos should undergo appropriate pre-processing procedures, such as scaling, normalisation, and augmentation.
- In order to preserve consistency and prevent bias in results, image enhancement techniques should be used consistently.

2. Standards for Model Development:

- Both built-in and custom models should be precisely defined and explained in terms of their architecture, layers, activation mechanisms, and other pertinent factors.
- The designs of custom models should be supported by their applicability to the issue at hand and performance improvements over built-in models.
- To guarantee the reliability of results, appropriate model validation approaches such cross-validation should be utilised.

3. Dataset and Data Standards:

- The origin, scope, and details of the image and video datasets, particularly those containing parking lot feeds and images must be fully documented.
- It is important to follow all ethical guidelines when using license data photographs, including getting the right consent and protecting privacy.

1.7 Approved Objectives:

The approved objectives that are to be achieved by the end of the Capstone Project are as follows -

1. To identify the number plate of the vehicle entering the parking space and the data on it.
2. To identify the vacant spots in the parking area using live video feed.
3. To record the time a vehicle enters and exits a parking spot.
4. To display the status of parking spots, the time stamp information, and the authorization status of vehicles.

1.8 Methodology:

The steps mentioned below depict the methodology that we, as a team, will be following, in order to successfully achieve the objectives mentioned in the project proposal:

1. **Designing the System architecture**: Based on the requirements, design the system architecture. This involves selecting the appropriate hardware, such as cameras and sensors, and software, such as a database to store information about parked vehicles.

2. **Develop the parking spot detection algorithm**: The next step is to develop a CV algorithm that can detect parking spots. This algorithm should be able to identify whether a spot is occupied or available in real-time. The algorithm will be based on OpenCV, that can be used to classify the parking spots, or simpler image processing techniques, such as edge detection and thresholding.
3. **Develop the time stamp check algorithm**: The time-stamp algorithm should be able to record the time a vehicle enters and exits a parking spot. This can be done by using a camera to capture an image of the license plate as the vehicle enters and exits the parking spot. The algorithm can then use image processing techniques to extract the license plate number and record the time.
4. **Develop the OCR algorithm**: The OCR algorithm should be able to read the license plate number and compare it with a database of authorized vehicles. The OCR algorithm can be based on machine learning techniques that are capable of processing sequential data, like characters in a license plate.
5. **Implement the user interface**: Develop a user interface that can display the status of parking spots, the time stamp information, and the authorization status of vehicles.
6. **Test and Deployment of System**: Finally, test the system to ensure it meets the requirements and deploy it in the parking area. Monitor the system to identify any issues and make necessary adjustments

1.9 Project Outcomes and Deliverables:

The Project outcome is estimated to be a well-defined system that use Machine Learning techniques along with the implementation of Computer Vision. It will be able to identify vacant parking spots in a parking space and keep a log of the entry of vehicles by using OCR algorithms to identify the data on the license plates of the vehicles that enter the parking space and if they are authorized to enter the area.

1.10 Novelty of Work:

The Computer Vision-Based Parking Management System described holds significant novelty in its approach to transforming traditional parking management processes through the integration of cutting-edge technologies. Its innovative aspects lie in several key areas:

1. **Real-Time Parking Availability**: The system's ability to provide real-time updates to drivers about available parking spots is a novel feature. This addresses the common frustration of drivers searching for parking spaces, enhancing user convenience and reducing congestion.
2. **Automated Detection**: The utilization of computer vision and machine learning algorithms for automated detection of vacant and occupied parking spots is a novel approach. It replaces manual oversight with an intelligent system that continuously monitors and updates parking availability.
3. **Entry and Exit Time Recording**: Accurately recording entry times using license plate recognition technology and associating them with vehicles is an innovative feature. This improves billing accuracy, transparency, and dispute resolution

2. Requirement Analysis

2.1 Literature Survey

2.1.1 Theory Associated with Problem Area

There are a few theories that are associated with the problem area of parking management:

- **The Theory of Constraints**: This theory states that the performance of a system is limited by its weakest link. In the context of parking management, the weakest link could be the number of parking spaces available, the efficiency of the parking enforcement system, or the willingness of drivers to pay for parking.
- **The Queuing Theory**: This theory studies the behaviour of queues, which are waiting lines. In the context of parking management, the queuing theory can be used to model the flow of traffic into and out of parking lots, and to predict the amount of time that drivers will have to wait for a parking space.
- **The Economics of Parking:** This field of study examines the economic aspects of parking, such as the demand for parking, the cost of providing parking, and the impact of parking on traffic congestion.

2.1.2 Existing System and Solutions

There are a number of existing systems and solutions for parking management. Some of the most common ones include:

- **Parking guidance systems:** These systems use sensors and cameras to monitor parking occupancy and provide real-time information to drivers about available parking spaces.
- **Parking reservation systems:** These systems allow drivers to reserve parking spaces in advance. This can be helpful for drivers who need to park in a specific location, such as a hospital or airport.

- **Automatic number plate recognition (ANPR):** This technology can be used to identify vehicles and track their movements. It can be used for parking enforcement, as well as for other purposes, such as traffic monitoring.
- **Smart parking:** This is a term used to describe the use of technology to improve the efficiency of parking management. It can involve the use of any of the technologies mentioned above, as well as other technologies, such as sensors, cameras, and artificial intelligence

2.1.3 Research Findings for Existing Literature

Here are some of the research findings for existing literature on computer vision-based parking management systems:

S.No	Roll No.	Name	Paper Title	Tools/Technology	Findings	Citation
1	102003473	Ankur Garg	Computer Vision based Parking Optimization System (2022)	Python	Suggested use of a system that uses cameras to find and identify the license plates of cars that enter and leave the parking lot with difficulties encountered in implementing the suggested system.	S Chandrasekaran, J. M. Reginald, W. Wang, and T. Zhu. Computer Vision based Parking Optimization System (2022). arXiv preprint arXiv:2201.00095

2			Computer Vision on a Parking Management and Vehicle Inventory System (2020)	Python	Computer Vison based system that managed parking spaces and monitored vehicles in the parking lots	A. D. M. Africa, A. M. S. Alejo, G. M. Bulaong, S. R. Santos and J. K. Uy. Computer Vision on a Parking Management and Vehicle Inventory System (2020). International Journal of Emerging Trends in Engineering Research, Vol. 8(2), 323-332.
3	102003722	Kunal Ranjan	Automatic Number Plate Recognition System for Vehicle Identification Using Optical Character Recognition (2009)	Python	Implementation of a system that employed OCR to identify vehicles. The technology was intended to be implemented in real-time.	M.T. Qadri and M. Asif. Automatic Number Plate Recognition System for Vehicle Identification Using Optical Character Recognition (2009). International Conference on Education Technology and

						Computer, 335-338
4	102003170	Mandeep Kaur	Computer Vision in Automated Parking Systems: Design, Implementation and Challenges (2017)	Python	Various image processing techniques. Concluded that the use of IR imaging and multiple cameras was important	M. Heimberger, J. Horgan, C. Hughes, J. McDonald and S. Yogamani. Computer Vision in Automated Parking Systems: Design, Implementation and Challenges (2017). Image and Vision Computing, Vol. 68, 88-101
5	102003078	Prisha Kwatra	Smart Vehicle Parking System Using Computer Vision and Internet of Things (IoT) (2021)	Python	Use of IoT and Computer Vision technologies to automate the parking process	O. Taylor, P. S. Ezekiel, and V. T. Emmah. Smart Vehicle Parking System Using Computer Vision and Internet of Things (IoT) (2021). European Journal of Information Technologies and Computer Science, Vol. 1(2), 11–16.

6			The Smart Parking Management System (2020)	Python	Novel system using IoT and Cloud Computing to identify vacant spots in parking area	Amira A. Elsonbaty and Mahmoud Shams. The Smart Parking Management System. International Journal of Advanced Computer Science and Applications (2020). Vol. 12, no. 4, 171-177
7	10203012	Jayesh Mohan Saxena	Research Review on Parking Space Detection Method(2021)	Python	Use of computer vision-based methods, magnetic field sensors, and ultrasonic sensors for locating available parking spots	] Yong Ma, Liu Yangguo, Lin Zhang, Yuanlong Cao, Shihui Guo, and Hanxi Li. Research Review on Parking Space Detection Method. Symmetry - 2021; Vol. 13(1):128
8			A Computer Vision-Based Roadside Occupation Surveillance System for	Python	Use of video steam to categorize roadside occurences and then alert	George To Sum Ho, Yung Po Tsang, Chun Ho Wu, Wai Hung Wong, and King Lun Choy. A

			Intelligent Transport in Smart Cities (2019)		authorities in case of any unusual activity.	Computer Vision-Based Roadside Occupation Surveillance System for Intelligent Transport in Smart Cities (2019). Sensors 2019; Vol. 19(8):1796.

2.1.4 Detailed Problem Analysis

Here are some of the problems that have been identified with computer vision-based parking management system:

- **Accuracy:** The system should be able to accurately detect vehicles, even in challenging conditions, such as low light or heavy traffic.
- **Scalability:** The system needs to be able to handle a large number of vehicles. The system should be able to track the occupancy of a large number of parking spaces in real time.
- **Usability:** The system needs to be easy to use. The system should be easy to install and maintain, and it should be easy for drivers to use.
- **Privacy:** The system should not violate the privacy of drivers. The system should not collect or store any personal information about drivers, such as their license plate number or their location.

2.1.5 Survey of Tools and Technologies used.

Here are some of the tools and technologies that are used in computer vision-based parking management systems:

- **Cameras:** Cameras are used to capture images of the parking lot. The type of camera that is used will depend on the specific requirements of the system. For example, a wide-angle camera may be needed to capture a large area, while a high-resolution camera may be needed to accurately detect vehicles.
- **Computer vision libraries:** These libraries are used to process the images captured by the cameras and extract the relevant information quickly and easily. They are based on pre-defined architecture hence they perform well. The programs using these will need to be able to detect vehicles, as well as track their movements. These include OpenCV, CvZone and Pillow.
- **Database:** The Database is used to store the information extracted from the images. This information can be used to track the occupancy of parking spaces, guide drivers to available parking spaces, and enforce parking regulations. Currently, due to the limited scope of the project, flat files of .csv extension are used.
- **A user interface**: This is used by users to interact with the system. The user interface should be easy to use and understand, and it should provide users with the information that they need. The user interface displays all information very clearly to the user.

2.2 Software Requirement Specification

2.2.1 Introduction

2.2.1.1 Purpose

- Our aim is to provide drivers with real-time information on the availability of parking spots, thereby improving the overall parking experience and reducing parking time.
- Additionally, to allow parking lot managers to optimize parking lot usage, minimize congestion, and improve revenue generation by maximizing the utilization of available parking spaces.

- Also preventing unauthorized access and reducing the risk of theft and other security issues enhancing of overall parking security

2.2.1.2 Intended Audience and Reading Suggestions

The intended audience for our project are the stakeholders involved in the development and implementation of the system. This may include the parking lot owners, the drivers, the city government, and the software developers.

Some general reading suggestions includes:

- **Chandrasekaran et al. [6]:** The report proposed a feasible strategy for improving parking management using computer vision-based approaches.
- **Markus Heimberger et al. [7]:** The paper suggested multiple cameras and infrared imaging can be used to address the challenges faced by computer vision-based automated parking systems.
- **Yong Ma et al. [8]:** The writers outlined the benefits and drawbacks of each technique and give instances of how they have been used in actual parking situations. Also, they described potential solutions for the problems that arise in parking spot recognition.
- **George To Sum et al [9]:** The authors have used real-world datasets to show the efficacy of the various methods, with encouraging findings in terms of accuracy and efficiency.

2.2.1.3 Project Scope

1. Computer Vision-Based Detection: Developing an object detection model using machine learning algorithms to identify vacant and occupied parking spaces in real-time through camera feeds.
2. Entry and Exit Time Recording: Implementing a system to accurately record the entry time of vehicles using license plate recognition (LPR) technology, which will also distinguish between authorized and unauthorized vehicles.

3. Real-Time Information Dissemination: Creating user interfaces, such as mobile apps and web platforms, to provide real-time information to drivers about parking spot availability, locations, and estimated arrival times.
4. Security Measures: Integrating security features by leveraging license plate recognition for detecting unauthorized access attempts and triggering security alerts.
5. Database and Reporting: Designing a database to store vehicle entry data, including license plate numbers, entry times, and vehicle types, and providing parking lot managers with tools for monitoring space utilization and generating reports.
6. User Experience Enhancement: Developing intuitive and user-friendly interfaces for drivers to facilitate easy navigation to available parking spots and provide a positive overall experience.
7. Testing and Optimization: Rigorous testing and fine-tuning of the system's algorithms and components to ensure accuracy, efficiency, and reliability in various scenarios.
8. Deployment and Integration: Deploying the system in a real parking area, ensuring proper hardware setup, connectivity, and integration with existing infrastructure.

2.2.2 Overall Description

2.2.2.1 Product Perspective

The product perspective refers to how our project fits into the larger context of parking systems, computer vision technology, and the needs of its users. It helps define the purpose, scope, and relevance of our project in relation to existing solutions and future developments. Here's how our project can be viewed from a product perspective:

1. **Drivers:** The product will help drivers to find available parking spaces more easily and quickly.

2. **Parking lot owners:** The product will help parking lot owners to optimize the use of their parking spaces and improve their revenue.
3. **City governments:** The product will help city governments to reduce traffic congestion and improve air quality

2.2.2.2 Product Features

The product has the following features:

1. To identify the number plate of the vehicle entering the parking space
2. To identify the vacant spots in the parking area using live video feed.
3. To record the time a vehicle enters and exits a parking spot.
4. To display the status of parking spots, the time stamp information, and the authorization status of vehicles.

2.2.3 External Interface Requirements

2.2.3.1 User Interfaces

Web App: It is a software application that is hosted on the internet and can be accessed through a web browser. Web apps are a popular way to interact with systems, as they are accessible to anyone with an internet connection. User will need interact through this web app for utilising the CV-based Parking Management System.

2.2.3.2 Hardware Interfaces:

The hardware interfaces needed for our project includes:

1. **Cameras:** They will be used to capture images of the parking lot.
2. **Computer:** It will be used to process the images from the cameras and to control the system.
3. **Database:** Needed to store the data from the cameras.

4. **Network:** Will be used to connect the cameras, the computer, and the database together.

2.2.3.2 Software Interfaces:

The software interfaces needed for our project includes:

1. **Computer vision software:** Main software which will be used to process the images from the cameras.
2. **User interface software**: The software by which user will interact with the system.
3. **Database software:** This software should be able to store and retrieve the data quickly and efficiently from the database.
4. **Networking software:** This software should be able to transmit the data reliably and securely.

2.2.4 Other Non-Functional Requirements

2.2.4.1 Performance Requirements

Performance requirements that our product, CV-based Parking Management System must achieve in its implementation includes the following:

1. **Speed:** The system should be able to detect vehicles in real time. This means that the system should be able to process the images from the cameras and detect the vehicles within a few seconds.
2. **Accuracy**: The system should be able to detect vehicles and the data of the License Plates accurately.
3. **Reliability:** The system should be reliable and should not fail often. This means that the system should be able to detect and classify vehicles consistently without errors.

4. **Security:** The system should be secure and should protect the data that it is processing. This means that the system should be protected from unauthorized access and tampering

2.2.4.2 Safety Requirements

Safety requirements ensure that our project operates within ethical, legal, and technical boundaries to protect user data, maintain accuracy, and prevent any adverse effects. Given are some safety requirements to consider in context of our product:

1. The system should not violate the privacy of individuals; This means that the system should not collect or store personal information about individuals without their consent.
2. The system should be able to operate safely in a variety of environments, such as inclement weather or low light conditions; This means that the system should be designed to be robust and reliable.
3. The system should be properly maintained; This means that the system should be regularly inspected and repaired to ensure that it is operating safely.
4. The system should be easy to use and understand; This means that the system should be designed so that it can be used safely by a variety of users, including those with disabilities.

2.2.4.3 Security Requirements

Security requirements ensure the protection of sensitive data, prevent unauthorized access, and safeguard the integrity and confidentiality of our project. Given that the travel data of any user is sensitive and our project involves processing such data, here are some security requirements to consider:

1. The system should be protected from unauthorized access; This means that the system should be designed to prevent unauthorized users from accessing the data or the system itself.
2. The system should be protected from tampering; This means that the system should be designed to prevent unauthorized users from modifying or deleting the data or the system itself.
3. The system should be protected from data breaches; This means that the system should be designed to prevent unauthorized users from accessing the data, such as the personal information of individuals.

2.3 Cost Analysis

Cost analysis involves evaluating the financial expenses associated with developing, deploying, and maintaining our project. Considering the complexity and nature of our project, here are some cost-related aspects to consider:

1. **Hardware Costs:** The hardware costs include the cost of the cameras, the computer, the database, and the network. The cost of the cameras will depend on the resolution and features of the cameras. The cost of the systems will depend on the processing power and memory of the computer. The cost of the database will depend on the size and complexity of the database. The cost of the network will depend on the size of the network and the bandwidth requirements.
2. **Software Costs:** The software costs include the cost of the computer vision software, the database software, and the networking software. The cost will depend on the features that the software offers to the customer.
3. **User Interface and User Experience (UI/UX):** A project involving a user interface has to consider the costs of UI/UX design and development.
4. **Testing and Quality Assurance:** Include expenses related to testing tools and services used to ensure the quality of our project.
5. **Deployment and Maintenance:** Account for expenses related to deploying the project, including server setup, domain registration, and SSL certificates.

Maintenance Costs: Estimate ongoing costs for maintaining and updating the project, including server hosting, security updates, and bug fixes.

6. **Training and Education:** Team Training: Include costs for training team members on new tools, techniques, or technologies.
7. **Operational Costs:** Operational Resources: Factor in operational costs such as electricity, internet, and office space.
8. **Contingency:** Allocate a portion of the budget for unexpected costs or changes in project requirements.

2.4 Risk Analysis

Risk analysis involves identifying potential risks, assessing their likelihood and potential impact, and developing strategies to mitigate or manage these risks. Given the complexity of our project and the sensitive nature of medical data, here are some potential risks to consider in our risk analysis:

1. **Technical risks:** risk of the hardware or software failing, the risk of the system being hacked, or the risk of the system not meeting the requirements.
2. **Schedule risks:** risk of the project not being completed on time, the risk of the project going over budget, or the risk of the project not meeting the quality standards.
3. **Regulatory risks:** risk of the system not complying with the regulations, the risk of the project being delayed due to regulatory changes, or the risk of the project being fined for non-compliance.
4. **External risks:** Includes the risk of natural disasters, the risk of political instability, or the risk of economic downturn.

3. Methodology Adopted

3.1 Investigative Techniques

Investigation Technique for our project are as follows:

Technique	Description	Pros	Cons
Object Detection	**Detects vehicles within camera images using techniques like YOLO, SSD, Faster R-CNN, etc.**	**Real-time detection, Accurate positioning**	**Requires substantial computational power**
Semantic Segmentation	**Identifies pixels corresponding to different object classes (e.g., vehicles, road) in the image.**	**Fine-grained understanding**	**Resource-intensive**
Optical Flow	**Tracks the motion of objects in successive frames to estimate vehicle movements.**	**Good for tracking vehicle trajectories**	**Sensitivity to lighting changes**
Background Subtraction	**Identifies moving objects by subtracting a static background model from the current frame.**	**Simple and real-time**	**Sensitive to lighting and shadows**

HOG (Histogram of Oriented Gradients)	**Analyses the distribution of gradient directions in an image to detect vehicles.**	**Fast and efficient**	**Prone to false positives**
Template Matching	**Compares a template of a vehicle with portions of the image to locate matching instances.**	**Simple and straightforward**	**Sensitive to changes in viewpoint**
Deep Learning-based Classification	**Trains a neural network to classify images into occupied and vacant spots.**	**High accuracy and adaptability**	**Requires substantial training data**

Table 4: Investigative Techniques

3.2 Proposed Solution

The proposed solution is a computer vision-based parking management system that uses machine learning to detect available parking spaces. This system aims to provide drivers with real-time information on the availability of parking spots, thereby improving the overall parking experience and reducing parking time. Additionally, the system will allow parking lot managers to optimize parking lot usage, minimize congestion, and improve revenue generation by maximizing the utilization of available parking spaces.

3.3 Work Breakdown Structure

Activity	Month	February				March				April				May				June				July				August				September				October				November			
	Week	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Planning and Design																																									
Capstone Team Formation																																									
Mentor Selection																																									
Project Proposal Preparation																																									
Research into Existing works on the Topic																																									
Methodology Formation for the Project																																									
Define Project Scope and Requirements																																									
Selecting Development Tools																																									
Development																																									
Setting up Project Development Environment																																									
Developing Character Recognition System																																									
Implementing Entry-Exit logs for vehicles																																									
Building the Vacant Space detection System																																									
Integration and Deployment																																									
Integrating the development modules																																									
Deploying and Testing the system																																									

Table 5: Work-Breakdown structure

3.4 Tools and Technology

Hardware:

- High-resolution cameras (Fixed and PTZ) for capturing Parking Lot images.
- IoT Devices: For connectivity, data transmission, and control of barrier gates.
- Barrier Gates: Motorized gates to control entry and exit.
- Server Hardware: Powerful servers for real-time image processing and data storage.

Software and Technologies:

- Computer Vision Libraries**:**
    a. OpenCV: Open-source computer vision library for image processing.
    b. TensorFlow and PyTorch: Deep learning frameworks for implementing object detection models and Optical Character Recognition.
- Object Detection Models**:**
    a. YOLO (You Only Look Once): For real-time object detection.
    b. SSD (Single Shot MultiBox Detector): Another fast and efficient object detection model.

c. Faster R-CNN: Offers accurate object localization and classification.

- HTML, CSS, JavaScript, and frameworks like Flask for user interfaces.
- Documentation**:** Tools like Markdown, LaTeX, or Google Docs for creating user manuals and technical documentation.
- Monitoring and Maintenance**:** Logging and Monitoring: Tools like Prometheus, Grafana, or ELK Stack for monitoring system health. SSH for remote access and management of servers.
- Deployment**:** Docker for Containerization for consistent deployment across different environments and Kubernetes for Orchestration for managing containers in a clustered environment.

4. Design Specifications

4.1 System Architecture

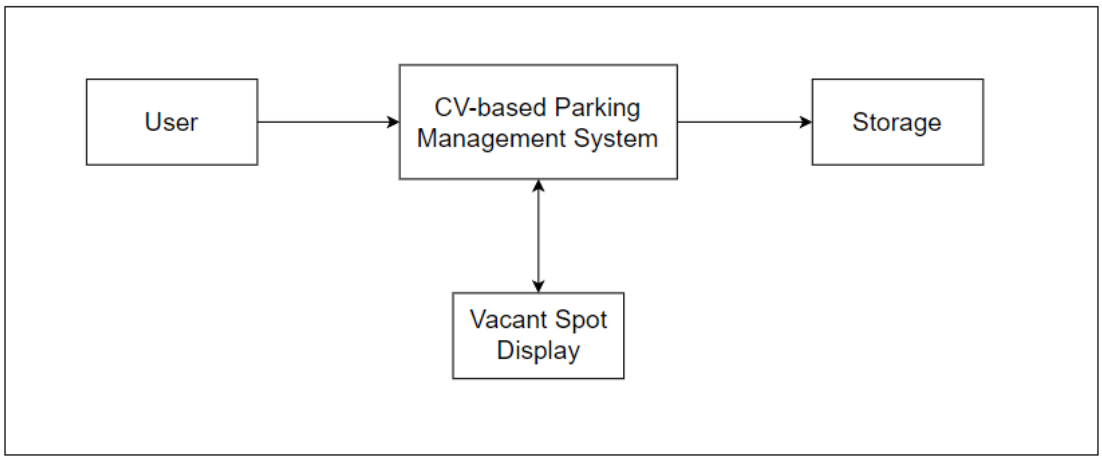


Figure 1: Block Diagram

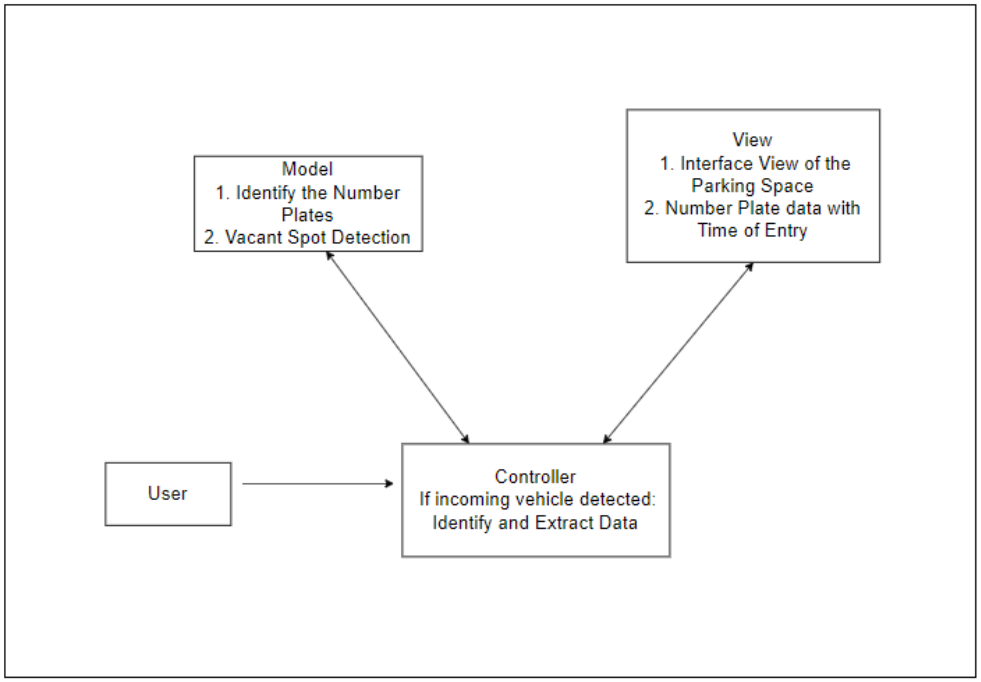


Figure 2: MVC Architecture

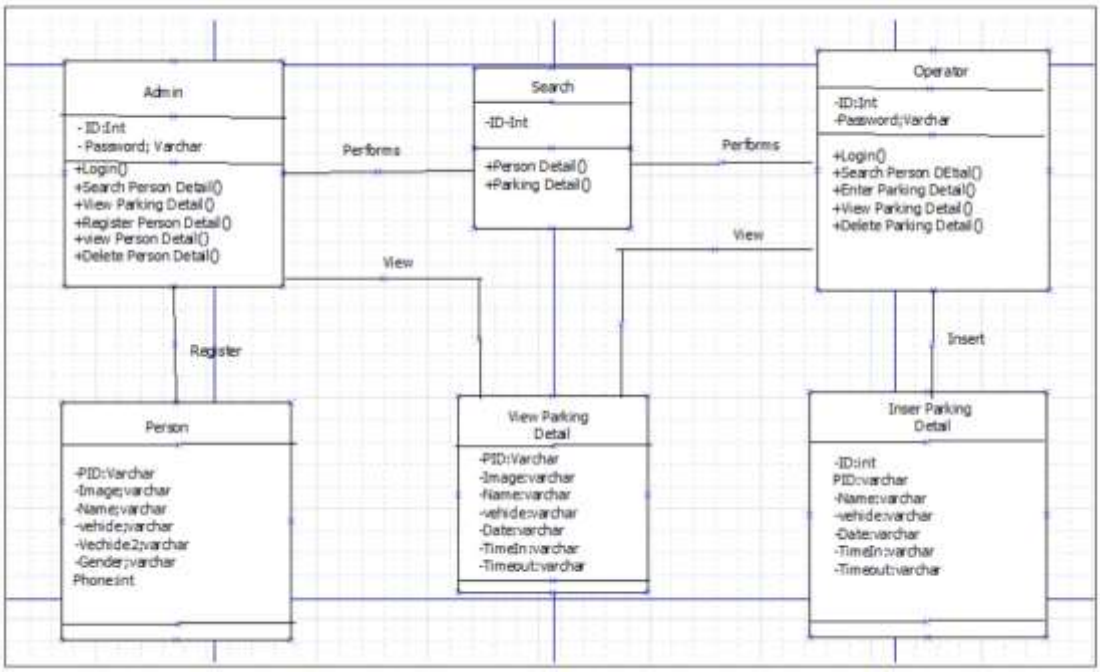


Figure 3: Class Diagram

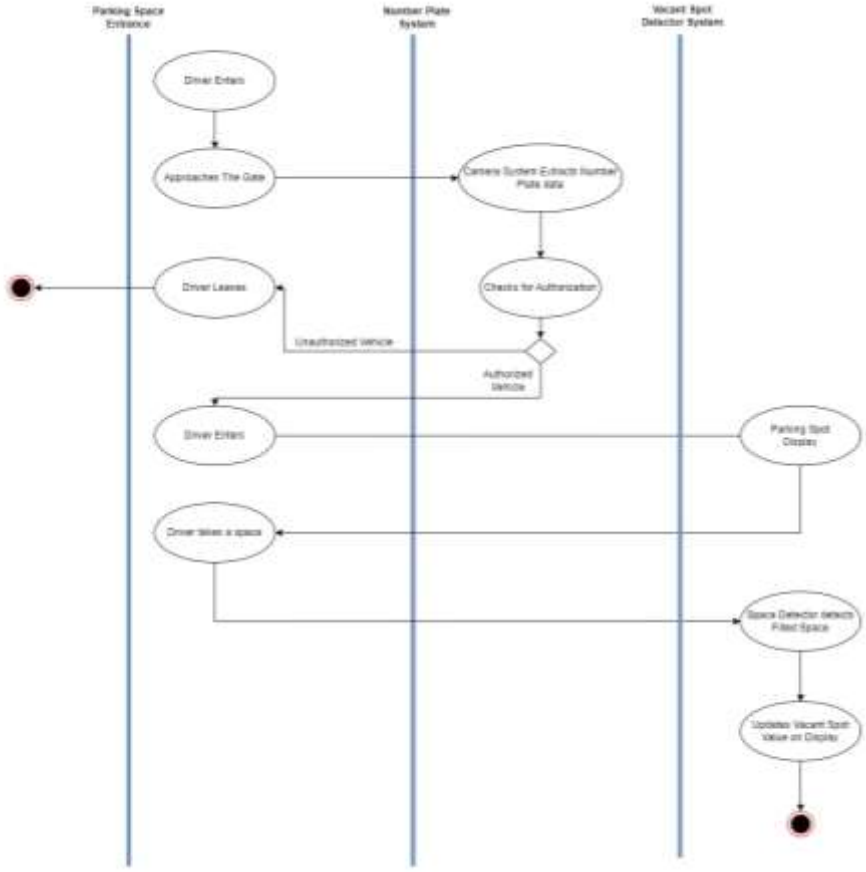


FIGURE 4: Swimlane Diagram

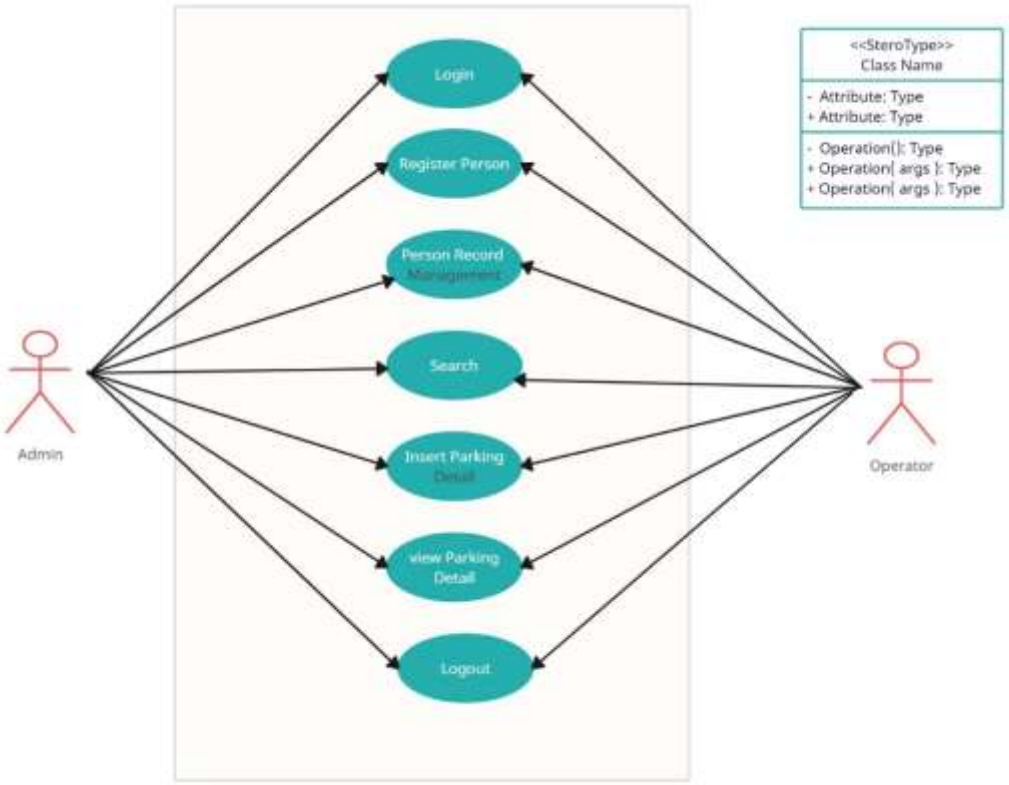


Figure 5: Use Case Diagram

4.2 Design Level Diagrams

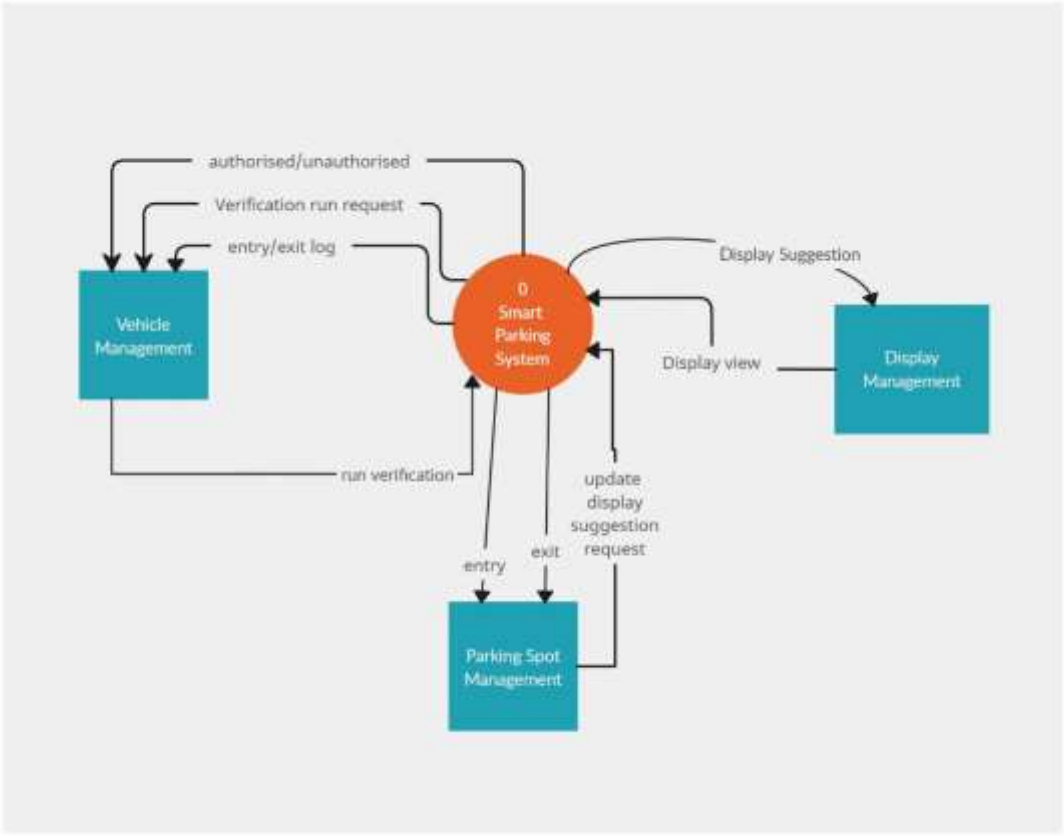


FIGURE 6: Level-0 DFD

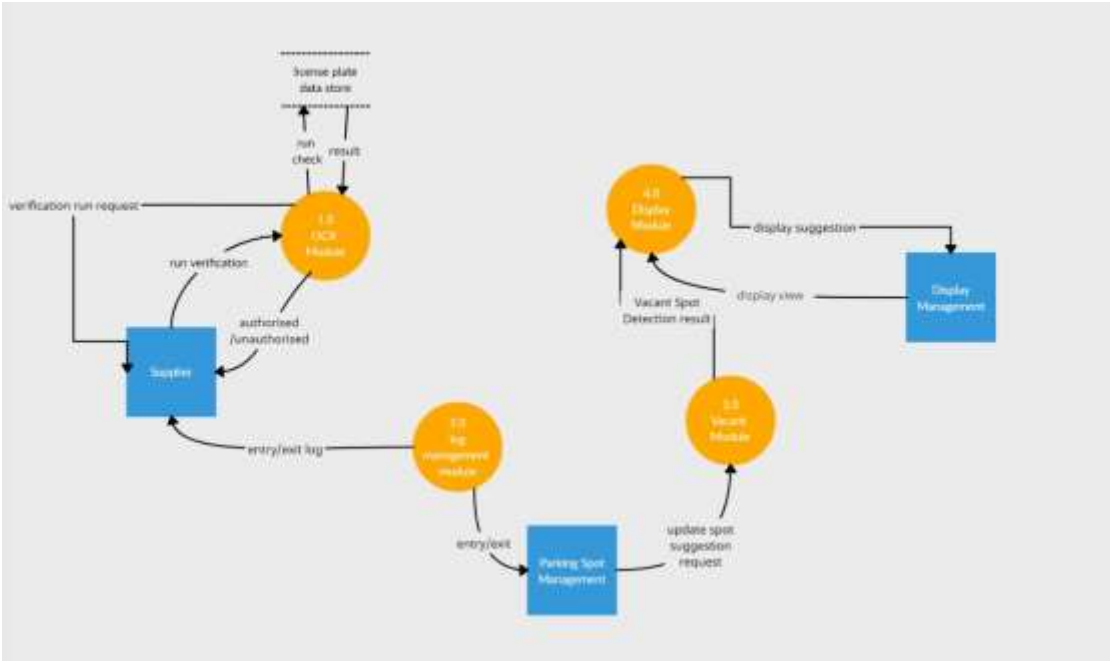


FIGURE 7: Level-1 DFD

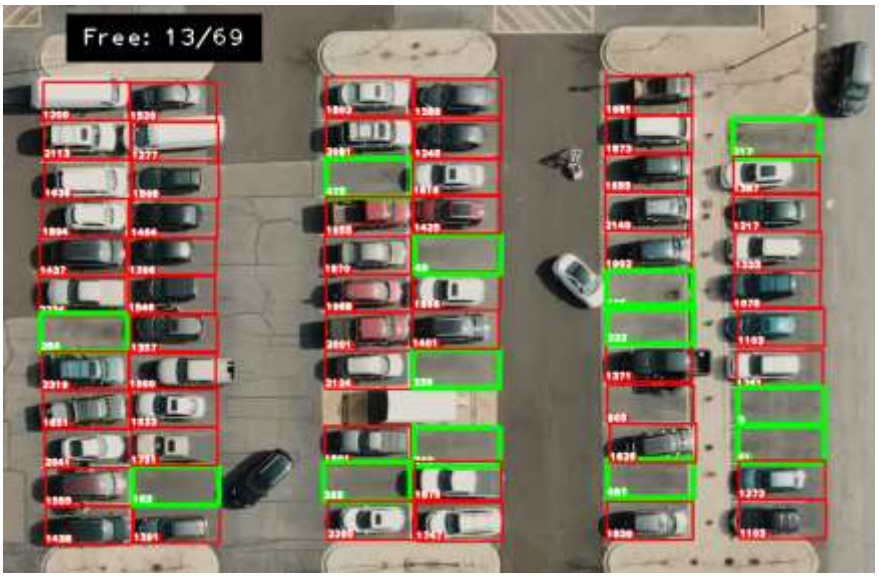


Figure 8: User Interface Diagram

5. Implementation and Experimental Results

5.1 Experimental Setup (or Simulation)

We built the experimental setup for our project in 2 phases. The first being Automatic Number Plate Recognition with OCR readers for authorization checks and the second being a Vacant Spot Detection System. The codebase, built in Python completely, acts as a bridge between the software and hardware components.

Our hardware component includes positioning high-resolution cameras at the entrance and throughout the parking area, all connected to a dedicated computer with specifications meeting the demands of the real-time image processing applications. The software backbone of ParkPro makes use of the Python programming language, which with key libraries such as OpenCV for Number Plate Detection and PyTesseract for performing efficient OCR is highly useful. The logic implemented in code for authorization is defined in a way, allowing for seamless access control for authorized vehicles.

Integrated with the ANPR functionality is the Vacant Spot Detection System, where cameras placed across the parking lot capture real-time feed of the area. Image processing techniques, such as Gaussian Filters for cleaning images and contour analysis, allow the system to accurately identify vacant parking spots. The dynamic visualization of these results on the user interface provides users with real-time and precise information regarding available parking spaces.

5.2 Experimental Analysis

5.2.1 Data (Data Sources / Data Cleaning / Data Pruning / Feature Extraction Workflow)

1. Data Sources: The main source of data for any of the modules of our system is Live Camera Feed. The system uses video feeds from efficiently positioned cameras covering the parking lot space, as well on the entry and

exit points that will be used for capturing real-time footage for vacant spot detection and number plate recognition.

2. Data Cleaning: The data cleaning phase of our project involves the implementation of various noise reduction and cleaning techniques such as the Gaussian Filter in order to clean the images received from the live feed for better processing.
3. Data Pruning: Involves excluding irrelevant information. This includes removing information such as other objects except cars that can disrupt the workflow form the data flow.
4. Feature Extraction: Feature Extraction is the process of extraction of features relevant to the objectives from Raw data. This phase of the data pipeline was achieved by using pre-trained models for vehicle detection and pre-trained Optical Character Recognition models such as EasyOCR or PyTesseract. The use of pre-trained classifiers is an addition to this list. Since they are pre-trained, they employ established architecture for the applications intended.

5.2.2 Performance Parameters (QOS parameters)

1. Vehicle Number Plate Segmentation Accuracy: Refers to the percentage of correctly segmented Number Plates from their surroundings.

2. Vehicle Detection Accuracy: Refers to the percentage of correctly identified vehicles entering or exiting the parking lot space.

3. Real-Time Updates Accuracy: The degree of precision to which the system evaluates the occupancy status of the defined parking spots.

4. Computational Resource Utilization: One of the QoS metrics that refers to the resource efficiency of the system.

5. Integration ability: The system’s ability to attach to existing hardware/software and still maintains its functionality while also having efficient communication with the existing hardware.

5.3 Working of the Project

5.3.1 Procedural Workflow

The entire project has been completed in 2 halves. The first being the development of the Number Plate Recognition System that had to perform the function of segregating Number Plates and the second being the development of the Vacant Spot Detection program that would identify the vacant spaces in the parking area.

1. Phase 1: Automatic Number Plate Detection

   The first phase involved choosing the appropriate techniques for differentiating the Number Plate from the entire car image of the live feed. Based on our literature review, we understood that to create a model from scratch was not a feasible option because of the fact that there is unavailability of publically number plates datasets that are verified and legally usable. Hence, to ensure the completion of our objective we took to making use of pre-trained classifiers from OpenCV such as the Haarscade Russian Number Plate classifier and pre-built OCR Models such as the PyTesseract module On top of this, to ensure better results, we added multiple image processing techniques such as the Gaussian Filter to reduce noise in the images.

2. Phase 2: Vacant Space Detection Module

   The second phase involved the development of the Vacant Spot Detection Algorithm. The module consisted of two main modules: main.py for real-time detection of vacant parking spaces and ParkingSpacePicker.py for manual selection and adjustment of parking spots. The program utilized computer vision techniques by using OpenCV for image processing and analysed video footage from a car parking, to identify available parking spots in real time. The code demonstrated a well-defined process, with the main system loading pre-existing parking space co-ordinates and continuously processing video frames to calculate the occupancy status of each space. In addition, the Parking Space Picker module provided an interface for the user to interactively select and adjust parking spot. The

code effectively combined image processing and a continuous data stream handling to create a real-time parking solution. The implemented code highlights the flexibility of the codebase and does have the opportunity for further improvements and enhancements.

5.3.2 Algorithms Used

The code utilizes various Computer Vision algorithms used for image processing. Some of them are mentioned below -

1. Gaussian Blur:
    a. Purpose: Applied to reduce noise in the image.
    b. Algorithm: 3X3 Gaussian kernel is used in the number plate' cleaning as well as in the mask for the vacant spot detection.
2. Adaptive Thresholding:
    a. Purpose: Used to create a binary image
    b. Algorithm: Adaptive Thresholding is used to increase the visibility of the parking space lines.
3. Median Blur:
    a. Purpose: Applied to further reduce salt-and-pepper noise in the image.
    b. Algorithm: 3X3 kernel used, strength 5.
4. Dilation:
    a. Purpose: Making parking spot lines more coherent.
    b. Algorithm: Expands the white regions in the image.
5. Count Non-Zero:
    a. Purpose: To determine the Occupancy Status of each parking slot.
    b. Algorithm: Counts the no. of non-zero pixel values in the parking slot where, higher non-zero count means the spot is occupied, while low count represents that the slot is empty.
6. Rectangle Drawing:
    a. Purpose: Drawing rectangles, making ROIs for parking slots
    b. Algorithm: Facilitated in making pickle model of ROIs
7. Mouse Click Event Handling:

a. Purpose: Used in the ParkingSpacePicker.py file to select or deselect parking slots.

5.3.3 Project Deployment

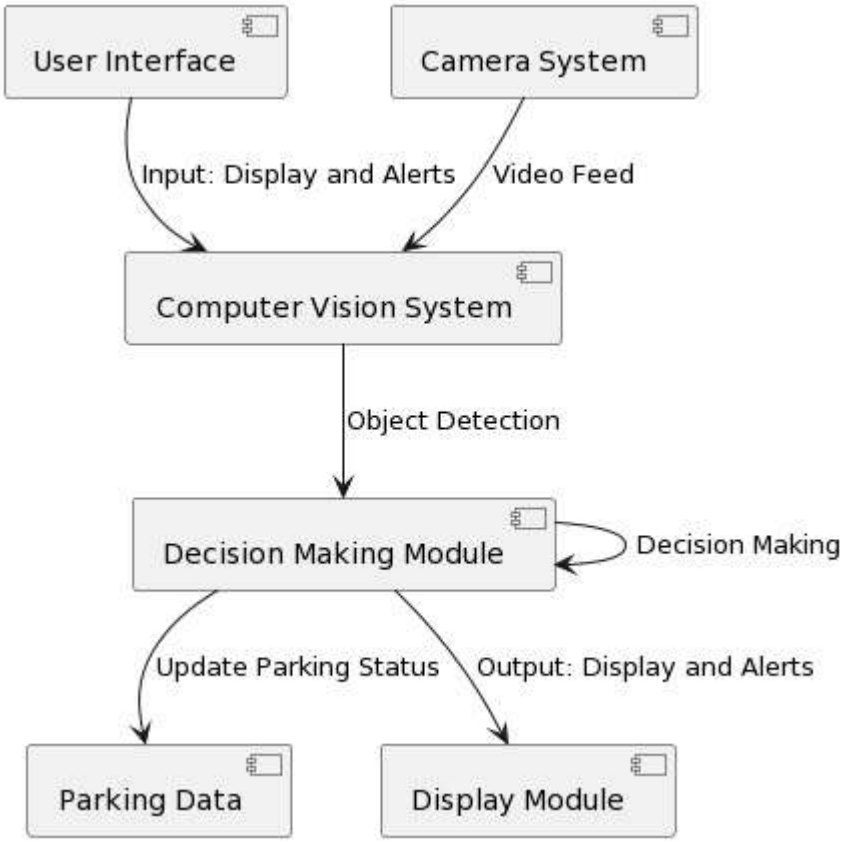


Figure 9: Deployment Diagram

5.3.4 System Screenshots

The attached screenshots display the system's functionalities and its structure.

1. Vacant Spot Detection

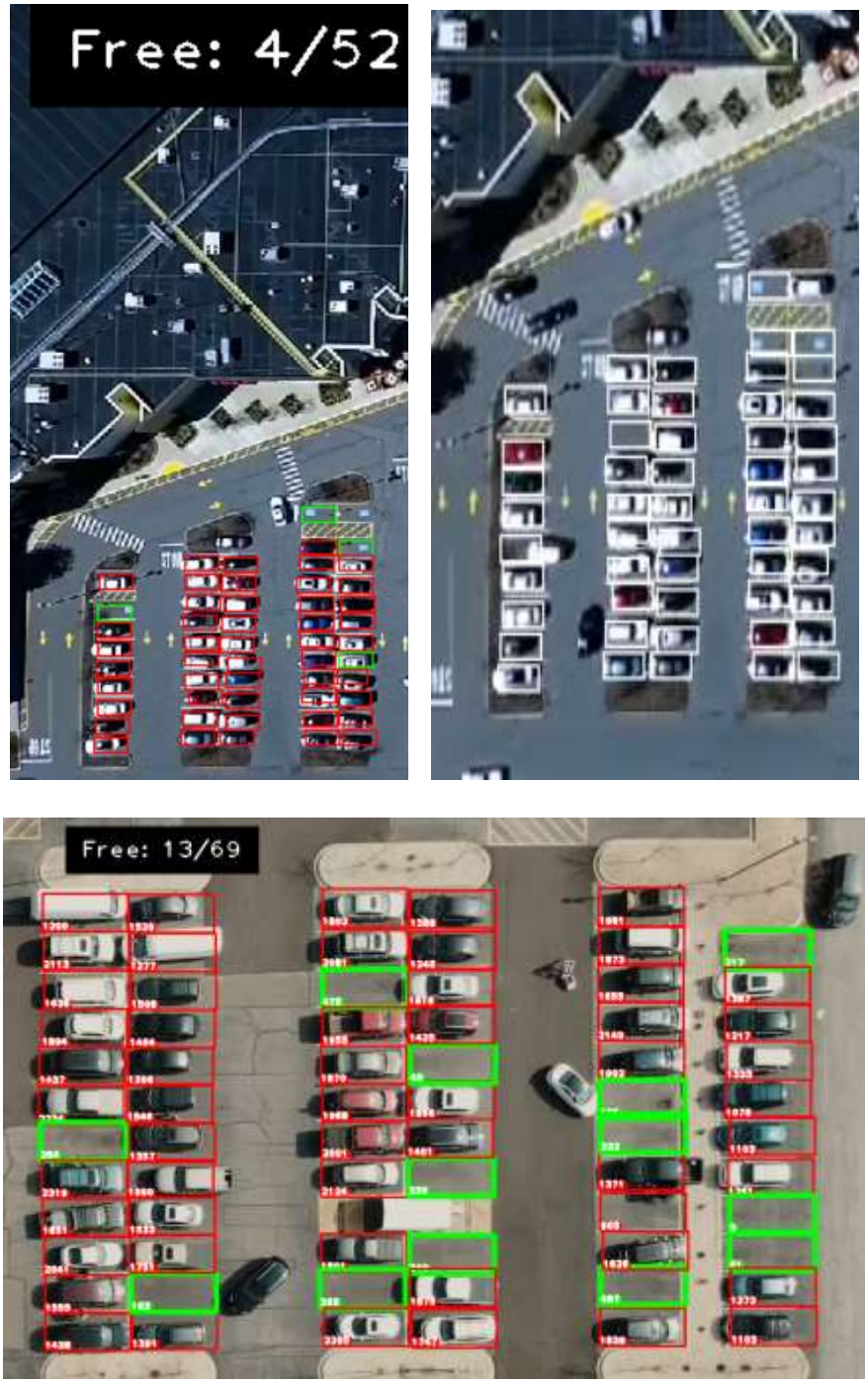


Figure 10: System Screenshots

Figure 11: System Screenshots

2. Number Plate Recognition and OCR

Figure 12: System Screenshots

The number plates are authorized based in the pre-defined number plates. This ensures that no unauthorized vehicle enters the region.

5.4 Testing Process

5.4.1 Test Plan

The goal of testing is to find potential flaws or vulnerabilities in a work product. It offers a way of testing the functionality of individual parts, assembled parts, and/or final products. It is a procedure for testing software to make sure it satisfies user requirements and expectations. The goal of testing is:

1. Ensuring that all the system components function as defined and intended.
2. Evaluating the system's performance under different conditions.
3. Determine any flaws, security holes, or usability problems in the system.

5.4.2 Features to be tested

The following features of the system need to tested:

1. System being able to accurately identify and track vehicles entering and exiting the parking area.
2. The system’s performance on real time updates of parking spot availability and occupancy.
3. The integration of the system with barriers, gates, and other existing parking facility infrastructure.
4. System’s functionality to be able to extract Number Plate data accurately and in as less time as possible.

5.4.3 Test Strategy

The following strategies are to be implemented for the testing of the system and its components.

1. White Box Testing: Involves examining the code structures and logical flow to verify the accuracy and how efficient are the Computer Vision Algorithms.
2. Black Box Testing: Involves validate system functionality, including user interfaces and real-time updates, without knowledge of internal workings.

3. Performance Testing: Involves evaluating the systems responsiveness under different conditions by measuring the time taken to act on certain stimuli.
4. Load Testing: Involves simulating long queue traffic scenarios to evaluate the system's ability to handle heavy loads and identify potential bottlenecks.

5.4.4 Test Techniques

1. Unit testing: Unit testing involves creating multiple test cases that confirm that the core programmable logic is working as intended and that the programme on receiving input produces a valid output. It is the process of testing each software unit of the application after it is finished and before it is integrated. Unit tests evaluate a particular feature or function, system configuration, or process at the component level.

2. System testing: System testing verifies that all requirements are met by the integrated software system. The configuration-oriented system integration test is an illustration of a system test. System testing focuses on pre-driven process connections and integration points, and is based on process flows and descriptions. Hence, ensuring system validation.

3. Integration testing: The purpose of integration tests is to evaluate integrated software components to see if they function as a single unit. Event-driven testing prioritises the fundamental result. Unit testing successfully indicates that each component was good on its own, but integration tests prove that the components work correctly and consistently together. The process of incrementally integrating two or more integrated software components on a single platform to identify interface flaws that lead to failures is known as software integration testing. Verifying error-free component interaction is the task at hand. This testing examined how Python files interfaced with the website's backend

5.4.5 Test Cases

1. Number Plate Detection Unit:
    i. Verify the process of identifying Number Plates.
    ii. Check for multiple Vehicles in a frame and accurately identify and distinguish between the number plates of each vehicle in the frame.
2. OCR and Time Unit:
    i. Verification of the error handling process of the unit and providing signal in case characters aren't accurately recognized.
    ii. Checking the unit for efficient handling of special/uncommon symbols found in number plates.
    iii. Checking for accurate updating of time stamp on the entry/exit of vehicles.
3. Vacant Space Detection Unit:
    i. Checking the defined parking lot spaces for empty status
    ii. Checking the defined parking lot spaces for occupancy status in case of a vehicle entering it.
    iii. Checking the modules performance regarding detection of other objects that might disrupt functioning of the unit.
4. Performance Testing:
    i. Conducting load testing with different, publically accessible video feeds, to evaluate system performance under various loads.

5.4.6 Test Results

S.No.	Test Cases	Result
1	Successful identification of the number plate of the vehicle entering the parking space.	Successful

2	Checking for, and segmenting multiple number plates, if in view.	Successful
3	Recording the time a vehicle enters and exits a parking spot	Successful
4	Identifying the vacant spots in the parking area using live video feed	Successful
5	Displaying the status of parking spots based on occupancy status.	Successful

Table 6: Table of Test Results

5.5 Results and Discussions

1. Number Plate Identification Module:
    a. Accurately identified vehicle number plates as OCR (Optical Character Recognition) technology has been effectively integrated for effective plate reading.
2. Vacant Spots Identification Module:
    a. This module uses computer vision-based image processing and a live video stream to identify vacant parking spaces in real-time.
    b. Decreased average time it takes for cars to locate parking spots.
3. Time Tracking Module:
    a. Precise documentation of every vehicle's arrival and departure times.
    b. This module may yield information on peak hours and the average length of time spent parking.
4. User Interface Module:
    a. Shows the authorized status of the car, the status of the parking space, and the timestamp.
    b. Interface that is easy to use for both administrators and users.

Overall System Results and Discussions:

- Improved parking system efficiency overall.

- Improved security with precise identification of license plates.
- enhanced user experience thanks to effective spot identification and real-time information.

5.6 Inferences Drawn:

Upon completion of the project, we drew the following inferences:

1. Number Plate Identification Module:

When this module is implemented successfully, efficient, and precise vehicle identification as it enters the parking area is achieved. This helps strengthen security protocols of the parking lot.

2. Vacant Spots Identification Module:

It is essential for this system to be able to recognize open spots in real-time utilizing a live video feed. This module makes driving easier for drivers, cutting down on time spent looking for parking and possibly even alleviating traffic congestion.

3. Time Tracking Module:

The timing of each car's arrival and departure from its parking space is recorded, and this information is useful for examining parking trends. Peak hour identification, efficient operation, are all possible with this data.

4. Status Display Module:

Users benefit from the transparency and simplicity provided by the parking place status display, timestamp information, and vehicle authorization status display

Overall System Inferences:

1. Efficiency Gains: The parking system's overall efficiency is increased by the integration of these components. It improves security, eases traffic, and gives users a more seamless experience.
2. Data-Driven Decision Making: By analysing the gathered information, such as entry/exit timings and parking spot usage, well-informed decisions may

be made on the optimization of the parking facility, including modifying rates, determining peak hours, and enhancing management in general.

3. Improved User Experience: A favourable user experience is facilitated by the real-time status display and the effective identification of open places.
4. Authorization and Security: By integrating vehicle authorization status, the system becomes more secure by guaranteeing that only vehicles with permission can access the parking lot.
5. Scalability: The modularity of the system allows it to be adaptable to different parking areas and potentially integrating with other smart city technologies. We have shown two such cases itself in our report.

5.7 Validation of Objectives

S.No.	Objectives	Status
1	To identify the number plate of the vehicle entering the parking space and the data on it	Successful
2	To identify the vacant spots in the parking area using live video feed	Successful
3	To record the time a vehicle enters and exits a parking spot	Successful
4	To display the status of parking spots, the time stamp information, and the authorization status of vehicles	Successful

Table 7: Table of Objective Validation

6. Conclusions and Future Directions

6.1 Conclusions

The following conclusions were drawn from the process of development of such a system -

1. Improve parking: Using parking tools to easily monitor parking spaces in real time. This can enable more efficient parking by directing drivers to available spaces, reducing traffic congestion and optimizing space usage.
2. Security measures: By integrating vehicle permits, the system can distinguish between vehicles that are allowed to enter the parking area and illegal vehicles. This helps strengthen security measures to prevent unauthorized use and potential security threats.
3. Data-driven insights: The project generates important information about parking, frequency of permits for unauthorized vehicles, and peak times. Analysing this data can provide insights for better resource allocation, revenue enhancement and infrastructure planning.
4. User convenience: Improve the overall experience by providing users with information about parking spaces and ensuring that only vehicles are allowed to access the site. This helps increase customer satisfaction and loyalty.
5. Scalability and integration possibilities: The technologies and algorithms developed for this project can be expanded and integrated into larger projects in smart city or commercial parking management, thus contributing to the general planning and transportation of the city.
6. Compliance and Regulations: Depending on location and context, this project will help enforce parking regulations, meet safety standards and enforce regulations.

6.2 Environmental, Economic and Social Benefits

1) Environmental Benefits:

a. Reduced Emissions: Efficient parking spot detection minimizes the time vehicles spend circling in search of parking spaces, thereby reducing overall fuel consumption and harmful emissions, contributing to improved air quality and reduced carbon footprint.

b. Traffic Congestion Reduction: By guiding drivers to available parking spots, the system helps in reducing traffic congestion caused by vehicles circulating to find parking. This decrease in traffic flow can lower overall vehicle emissions and improve local traffic flow.

c. Optimized Land Use: Better parking management through spot detection can lead to more efficient use of parking spaces, potentially reducing the need for expansive parking lots. This may, in turn, pave the way for alternative land use, such as green spaces or sustainable developments, contributing to environmental preservation.

2) Economic Benefits:

a. Cost Savings: For drivers, the reduction in time spent searching for parking translates to savings in fuel costs and increased convenience. For parking operators or businesses, optimizing parking spaces can potentially lead to better revenue generation and cost savings through improved space utilization.

b. Potential Revenue Generation: Enhanced parking facilities that efficiently manage authorized vehicle access can attract more customers or tenants, leading to increased revenue for businesses or property owners.

c. Job Creation and Technological Innovation: The implementation and maintenance of these parking management systems can create jobs in technology development, maintenance, and management, contributing to economic growth.

3) Social Benefits:

a. Improved Accessibility: Efficient parking systems make it easier for individuals, including those with mobility challenges, to find parking closer to their destinations, enhancing overall accessibility.

b. Enhanced Safety and Security: Strict authorization measures ensure a safer parking environment by reducing the presence of unauthorized or suspicious vehicles, enhancing the sense of security for users.

c. Community Well-being: Reduced traffic congestion, lower emissions, and optimized urban spaces contribute to a more pleasant and healthier urban environment, positively impacting the well-being of residents and visitors.

6.3 Reflections

1. Team members gained experience working in a professional setting and developed problem-solving skills under time constraints through the generation of solutions to the queries. We also acquired the ability to effectively communicate with one another.
2. The group acquired knowledge of effective teamwork and gained exposure to the corporate environment. We acquired the ability to effectively manage tasks not withstanding our scholastic commitments. It instilled in us the leadership qualities necessary to see things from a different angle and assist others in completing tasks by the due date.
3. The members of the team acquired knowledge regarding the appropriate protocols for planning and documenting a project. We also gained knowledge on how to present our work in such a way that anyone who is not an expert in the same field can comprehend the essence of the project simply by reviewing the project documentation.
4. Every member encountered a unique set of obstacles that are inherent in the project-working process. In its entirety, the practical experience was outstanding. In addition to gaining practical experience in computer science, we also gained knowledge in the fields of machine learning and transformers. We gained knowledge in a variety of areas through this

project, including how to relate health parameters with recommendation system, high-level coding for implementing AI.

6.4 Future Work

1. Improving License Plate Detection: To enhance the accuracy and speed of license plate detection, we will delve into refining the process through a combination of techniques. Investigating the incorporation of additional pre-processing techniques is a key step aimed at improving image quality before the license plate recognition step. This involves exploring methods for noise reduction, contrast enhancement, and image normalization. Furthermore, we will conduct experiments to fine-tune the YOLOv8 model, a state-of-the-art object detection algorithm, specifically for the task of license plate recognition. Additionally, alternative Optical Character Recognition (OCR) libraries or models will be explored to ascertain whether more accurate text extraction can be achieved, leading to higher precision in license plate detection.
2. Advanced Data Logging and Analysis: Expanding upon the current entry-exit log system, the development of a dedicated database for storing entry and exit logs stands as a vital objective. This will facilitate efficient querying and reporting, enabling more comprehensive data analysis. By structuring the database to store relevant attributes such as timestamps, vehicle IDs, and parking spot IDs, we aim to derive valuable insights from the data. The database will be designed to handle substantial volumes of data, ensuring its scalability as the system usage grows.
3. Enhanced Vacant Parking Spot Detection: Our intention is to bolster the reliability of vacant parking spot detection by integrating more sophisticated computer vision techniques and potentially leveraging sensor-based solutions. Advanced object detection techniques rooted in deep learning will be explored to increase the accuracy of identifying vacant parking spots. Additionally, the integration of sensors, such as

ultrasonic or camera-based devices, will be investigated. These sensors can provide real-time occupancy information, complementing the visual detection system. Machine learning models will be implemented to predict parking spot availability based on historical data and event patterns, offering users real-time updates and optimizing the parking experience.

4. Real-time Navigation and Guidance: The development of a real-time navigation system for guiding users to available parking spots is a key project expansion. This involves integrating the vacant parking spot data with a map-based interface, granting users instant access to the availability status of parking spots. By incorporating pathfinding algorithms, we intend to calculate the shortest routes to the identified vacant parking spots, thus minimizing search times. Additionally, considerations will be made to seamlessly integrate the system with popular GPS navigation applications, enhancing the convenience and usability of the parking guidance.
5. Security and Privacy Enhancements: Ensuring the security and privacy of user data is paramount. This phase of the project involves implementing encryption mechanisms for sensitive information such as license plate numbers and user details. To enforce authorized access, a robust access control system will be developed, safeguarding both data and system functionalities from unauthorized usage. Addressing privacy concerns, we will provide users with transparent information about data collection and usage, enhancing user trust and compliance with data protection regulations.

7. Project Metrics

7.1 Challenges Faced

1. Business challenges: Creating an accurate and reliable parking system using sensors, cameras or other technologies can present challenges such as interference associated with different weather conditions, rare issues or lack of visibility of the station.

2. Privacy and Security Issues: The use of systems that collect and process traffic data may increase privacy concerns. It is very difficult to keep data secure, prevent it from being leaked or unauthorized, and comply with privacy laws.
3. Legal and Legal: Complying with local laws, obtaining appropriate permits, and dealing with legal issues regarding data collection, privacy handling, and traffic permits can pose serious challenges.
4. Solution and Confidence: It is important to maintain your constant performance and confidence in your body. Regular maintenance, upgrades and timely resolution of faults are issues that need to be managed properly.

7.2 Relevant Subjects

The subjects that we found relevant to our project includes -

1. Software Development
2. Artificial Intelligence
3. Computer Vision
4. Machine Learning

7.3 Interdisciplinary Knowledge Sharing

Sharing is an essential element in ensuring the success of a project, whereby the expertise and knowledge of one team member are readily accessible to the others whenever they require them. Group members engaged in a discourse regarding the practicality and viability of the concept throughout the duration of the endeavour.

Ancient Stoic rules and principles assisted us in remaining unified as a group. Due to the extensive scope and ideation demands of the project, as well as the limited proficiency of some team members in each technology utilized, knowledge sharing served to overcome the divide between those who were acquainted with the technology and those who were proficient in

it. Being students of the Computer Science department, we were familiar with the technologies and software used in our project involving computer software as the key player. The use of machine learning for model training and getting the optimal accuracy for our project.

7.4 Peer Evaluation Matrix

Evaluation By	Evaluation of				
	S1	S2	S3	S4	S5
S1	5	1	5	2.5	5
S2	5	5	5	5	5
S3	5	1.5	5	2.5	5
S4	5	1	5	5	5
S5	5	1	5	2.5	5

Table 8: Peer-Evaluation Matrix

S1- Ankur Garg (102003473)

S2- Jayesh Mohan Saxena (102053012)

S3- Kunal Ranjan (102003722)

S4- Mandeep Kaur (102003170)

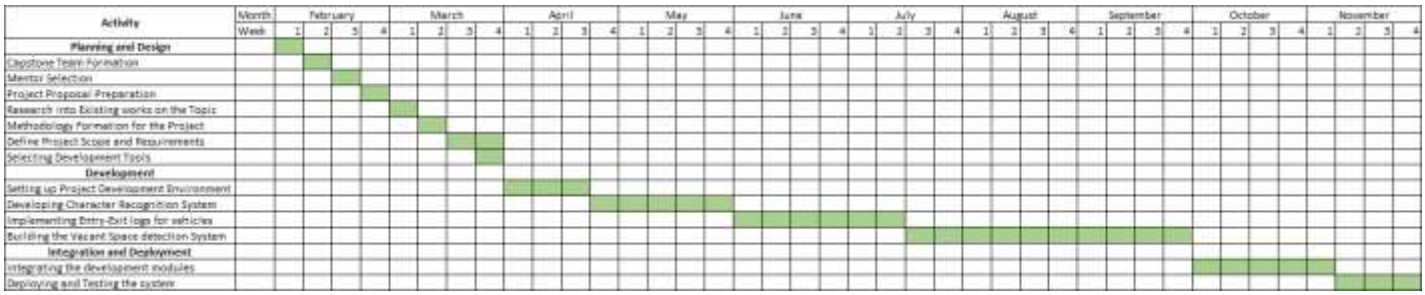
S5- Prisha Kwatra (102003078)

7.5 Role Playing and Work Schedule

The individual roles and responsibilities of each team member are as mentioned:

1. Ankur Garg: Computer Vision, Machine Learning
2. Kunal Ranjan: Documentation, Machine Learning
3. Prisha Kwatra: Machine Learning
4. Mandeep Kaur: Computer Vision

5. Jayesh Mohan Saxena: Documentation, Machine Learning



7.6 Student Outcomes description (SO) and performance indicators (PI)

SO	SO Description	Outcome
1.1	Ability to identify and formulate problems related to computational domain	Identified problem of inaccurate OCR extraction. The challenge is how to modify the models in order to attain a better performing OCR model.
1.2	Apply engineering, science, and mathematics body of knowledge to obtain analytical, numerical, and statistical solutions to solve engineering problems.	Applied engineering principles and mathematical concepts to develop solutions for challenges specific to the parking system problem, ensuring accurate detection and efficient use of parking space.
2.1	Design computing system(s) to address needs in different problem domains and build prototypes, simulations, proof of concepts, wherever necessary, that meet design and implementation specifications.	Successfully designed computing systems tailored for parking management, including prototypes and simulations that meet specifications for accurate vehicle detection and real-time updates.

2.2	Ability to analyze the economic trade-offs in computing systems.	Evaluated and considered economic factors when making decisions about the parking system's design, such as assessing the cost-effectiveness of the components.
3.1	Prepare and present variety of documents such as project or laboratory reports according to computing standards and protocols	Produced well-structured reports conforming to computing standards, effectively displaying findings related to the parking system’s performance and updates.
3.2	Able to communicate effectively with peers in well organized and logical manner using adequate technical knowledge to solve computational domain problems and issues	Learnt effective communication with team members, presenting technical knowledge logically to address issues in the parking system.
4.1	Aware of ethical and professional responsibilities while designing and implementing computing solutions and innovations.	Experienced awareness of ethical considerations in the design of the parking system, prioritizing security and privacy due to presence of sensitive data
4.2	Evaluate computational engineering solutions considering environmental, societal, and economic contexts	Addressed the impact of parking system solutions on the environment, society, and economy, tackling issues such as congestion and security

5.1	Participate in the development and selection of ideas to meet established objective and goals	Actively participated in the formulation and selection of concepts, thereby contributing to goals such as optimising parking space utilisation and improving security.
5.2	Able to plan, share and execute task responsibilities to function effectively by creating collaborative and inclusive environment in a team.	Effectively planed and shared responsibilities, and collaborated within the team for successful parking system development.
6.1	Ability to perform experimentations and further analyze the obtained results.	Proficiently conducted experiments, such as testing, and analyzes results to improve the parking system's accuracy and efficiency.
7.1	Able to explore and utilize resources to enhance self-learning.	Demonstrated the ability to effectively research and use resources to strengthen skills relevant to the improvement of parking facilities.

Table 9: Table of Student Outcomes

7.7 Brief Analytical Assessment

Q1. What sources did your team consult to identify potential project problems?

Ans. Our team had an initial understanding of the Capstone requirements and identified potential challenges. We extensively researched relevant literature, including research papers, journals from various sources to better understand the topic and its accompanying challenges.

Q2. What methods did your project team employ to address the identified problems?

Ans. Our team studied literature from various sources and journals to understand the problem and then employed multiple computer vision algorithms and techniques to perform image processing on live video feeds to achieve our objectives.

Q3. Did the project require a demonstration of knowledge in scientific, engineering, or fundamental principles? If so, how did your team apply this knowledge?

Ans. Several engineering subjects, including Software Engineering, Artificial Intelligence, Machine Learning and Computer Vision were integral to building our system. Their was use of Python during development and principles of all the above mentioned subjects were used.

Q4. How did your team manage responsibilities and communicate schedule information to coordinate design and manufacturing dependencies?

Ans. With a team of five members, we divided the project into manageable subtasks, with each individual focusing on specific responsibilities. Communication was facilitated through platforms like Google Meet and Offline group meetings.

Q5. What resources were utilized to acquire knowledge beyond the classroom for the project?

Ans. To enhance our understanding, we engaged with online tutorials, courses, blogs, documentation, and guides to grasp new concepts essential for the project.

Q6. Did the project foster an appreciation for solving real-life problems through engineering, and did it contribute to proficiency in software development tools and environments?

Ans. The project indeed instilled a greater appreciation for addressing real-life challenges through engineering solutions. Moreover, it significantly enhanced our proficiency in various software development tools and environments

APPENDIX A

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APPENDIX-B PLAGIARISM REPORT

NOTE: The highest plagiarism 4% has been detected due to the Thapar University report template.

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