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Original Article

Smart Parking System using IOT and Image Processing

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Abstract - *Considering the continuously increasing urban population and private vehicle ownership, a smart parking framework has become a fundamental necessity of the present times. According to various studies, nearly 30% of the urban traffic congestion occurs due to drivers searching for nearby parking spaces. To reduce traffic congestion and avoid the wastage of time and fuel, this research work offers an android-based smart parking system integrating IoT and image-processing technologies. The smart parking system proposed in this paper helps reduce the time and fuel consumption involved in searching for a nearby parking area, and also allows users to pre-book a parking slot in real-time. In addition, the app will also help the user to get to the parking area via the shortest route, for which the Google Maps API is used. Furthermore, the parking entrance will be fully automated, and charges will also be dynamic (time-based). A user may pay offline or online using a digital wallet or any payment gateway, resulting in the faster exit of vehicles. This approach helps to make the parking experience faster and smoother, and also reduces traffic inside the parking area. The suggested Smart parking system thus contributes to improving the operational efficiency of the parking operations, optimizing the utilization of parking space, and enhancing the overall user experience by providing a simple, automated, and congestion-free parking solution, which helps smooth traffic flow.*

Keywords - *Image Processing, Internet of Things, Smart parking system, Smart city, Number Plate detection.*

1. Introduction

According to the research by the Center for Science and Environment, in India, cars are left in parking lots more than 95% of the time and are only driven 5% of the time. According to various studies, nearly 30% of the urban traffic congestion occurs because drivers are searching for nearby parking spaces. To decrease traffic congestion and associated waste of time and fuel while searching for parking, it becomes essential to develop efficient and automated parking mechanisms. Now the question arises: where should a vehicle be parked for such lengthy durations? The answer lies in the availability and management of parking lots. The first challenge brought about by the rapid growth in automobile ownership worldwide is “cruising for parking”. Studies indicate that drivers looking for parking areas account for nearly 30% of city traffic on average (Zhu 2020).In this section, the increasing need for parking areas, the concept of Smart Parking, and the rising demand for smart systems as a replacement for conventional parking setups have been discussed.

1.1. Increasing Need for Parking Area

Due to the accelerated industrialization around the world, there is higher growth in urban economies, incomes, and living standards alongside high population growth. This has led to a steady rise in private vehicle ownership (Parmar et al 2020). Because of the relatively low cost of private vehicles and the minimal or free parking fees in India, as shown in Figure 1 (mohua.gov.in 2016), most Indian people prefer private vehicles over public transport. This preference has caused a substantial increase in parking demand in Indian cities (Fahim A. 2021).

1.2. What is Smart Parking

Smart Parking is a technology-driven parking strategy that combines human innovation and modern sensing and automation technologies. Its goal is to achieve efficient, fast, and high-density parking with minimal use of critical resources such as time, space, and fuel (Ashutosh Kumar Singh et al. 2019).

1.3. Need for Smart Parking

According to a market analysis by ITS America (Zhu 2020), it is anticipated that 30% of the traffic congestion in the cities is because of drivers looking for nearby parking areas. This also results in a waste of fuel and time. According to a survey, nearly 1 million barrels of oil are wasted every day, all

around the world, in searching for a parking area. Continuously increasing traffic jams, the uncertainty of the availability of parking areas nearby, and the unfair and hectic payment of parking fees created the need for an upgraded Smart Parking system. The demand for smart parking systems is growing day by day as the number of private vehicles is increasing continuously, as shown in Figure 2 (*statista.com* 2023).With the use of Smart Parking, people looking for a parking space can find it in the most efficient way possible, and companies or municipalities can optimize their parking areas more effectively. This makes cities more livable, safer, and less congested. Smart parking technology will help optimize the use of parking space, make parking operations more efficient, and facilitate smoother traffic flow.To fulfill all these requirements, this article offers an android-based smart parking system integrating IoT and image-processing technologies. The novelty of this work lies in combining IoT-based automation, dynamic time-based pricing, and Google Maps integration for real-time navigation, thereby improving parking efficiency and user convenience.

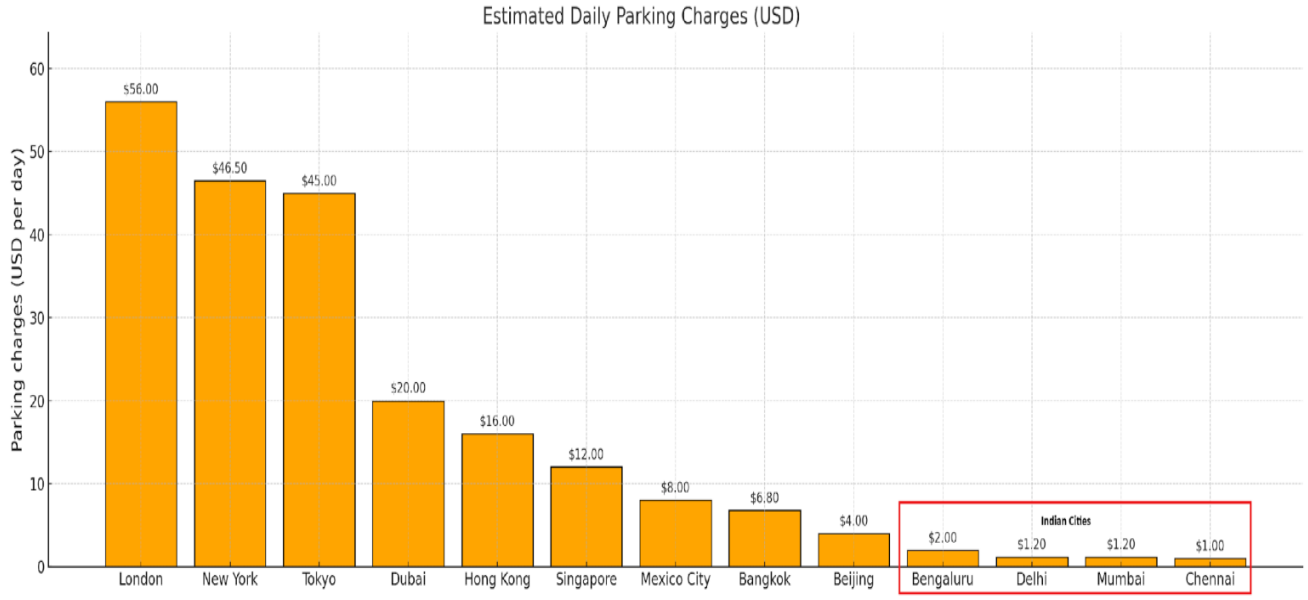

Fig. 1 Graph daily parking charges in cities across the globe [3]

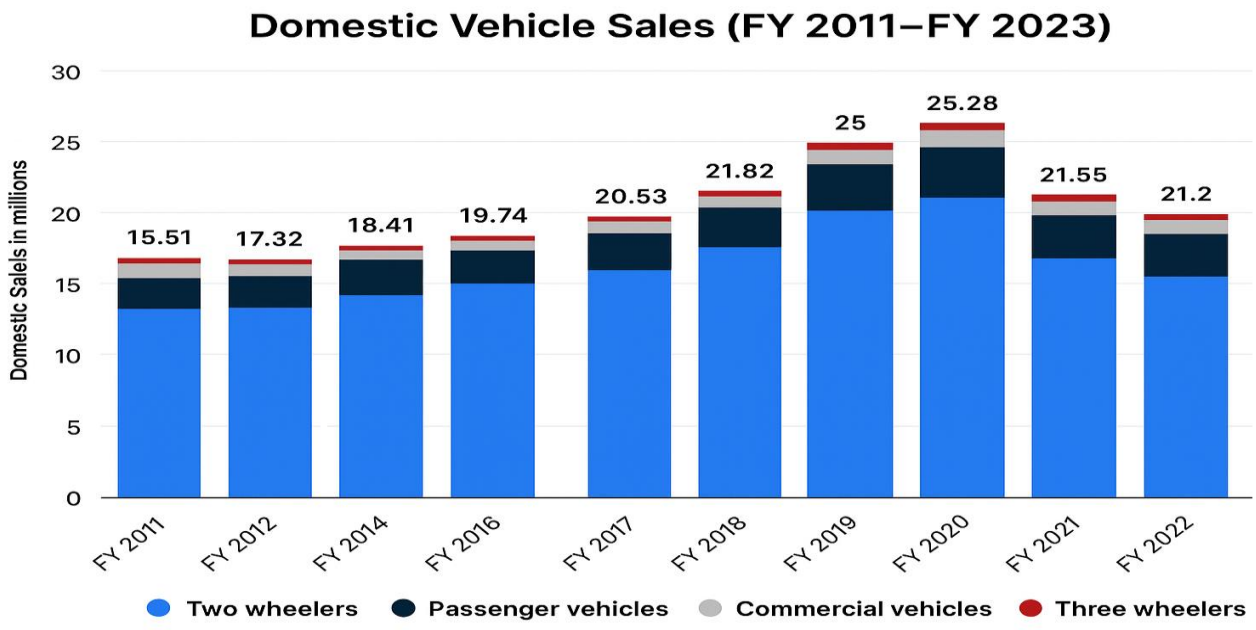

Fig. 2 Total registered vehicles in India(in millions) yearwise [6]

The remaining of this work is structured as follows:

- Section 2 presents a review of the state-of-the-art related studies.
- Section 3 provides a detailed methodology of the proposed system.
- Section 4 displays the performed experiments and the corresponding results.
- Section 5 concludes the contributions and findings of this work.

2. Related Work

Conventional parking systems face several operational and management challenges in the urban parking environment. Therefore, Smart Parking Systems (SPS) have been developed to address these limitations. Various methods and studies are being carried out to overcome the problems of parking areas (Tătulea P 2019; Lizbetin J. 2020; Safitri R 2020; Hwang S. E. 2018). Some of these recent technologies and approaches are summarized below. The following sections provide explanations of the various smart parking systems and technology types.

Real-Time updates IoT based sensors are used to collect real-time data about the availability of parking slots and the location of vehicles inside the parking areas. This data is transmitted to the cloud platform, which can be accessed from any location around the globe with an internet connection, giving rise to the Cloud Of Things (COT) (Vaishnavi D. 2018). Through this architecture, nodes can be controlled and monitored remotely. Such systems provide real-time information about the status of parking spaces and vehicle locations through a mobile application interface. With the help of mobile applications, users can also reserve a parking slot for his/her vehicle in advance from any location (Elakya R 2022).

Related Algorithms to Find Nearest Parking Location. An algorithm and network architecture technology are used to increase the effectiveness of the online smart parking system. With the help of algorithms, users can find the cheapest and nearest parking spaces in his/her current location. The user can access the cloud server using a mobile application and can find the real-time information/status of the parking area. By using this algorithm, users' time wasted in search of nearby parking will also be reduced significantly.

Use of Wireless Sensor Network (WSN) and RFID– With the help of wireless sensor nodes along with a mobile application, users can locate a nearby parking location. On-board units are used as a source of communication with the other vehicles. By using this wireless technology, the system can achieve high efficiency and accuracy. Users can park their vehicle at any parking slot in the parking space. A ticked ID and a secret key are used to provide to the user, which are only known to the user. In other words, only the user knows the key, which is necessary to pick up the vehicle. RFID consists of an antenna, a transponder, and a transceiver. Through the RFID reader's antenna, the transceiver or RFID reader queries the transponder to read its distinctive ID (Pala Z. 2007). To determine if a parking space is occupied, RFID reader antennae are placed in the parking lot, and the RFID tag is placed inside the vehicle. The state of the parking place is changed to occupied when the RFID reader reads a vehicle's tag (Idris M.). The user will get an RFID card for their vehicle, so the user does not have to carry a paper/plastic ticket. The user does not need to carry any paper ticket, as the user receives an RFID card. The technology used here is very low-cost. To protect the user's privacy, security features must be improved.

Use of Google Map API– This paper (Elakya R 2022) provides a successful approach to reduce the problem of availability of parking slots in a real-time scenario, and hence decreases the consumption of time. For this situation, the information is transmitted locally using information filtering devices. After this, the signal is transmitted for evaluation and processing using machine learning algorithms through the cloud. This article (Amala C.2022) utilizes a mobile application that interfaces clients to real-time traffic conditions with the help of the Google Map API. This way, you will avoid traffic jams and save a lot of time that was wasted in traffic jams.

License Plate Detection and Text Extraction– The real-time intelligent parking system, which helps the user in finding information about free parking slots and which also provides the nearest parking space availability, can be efficiently designed by utilizing the Internet of Things (IoT). The presented work in this article (Elakya R 2022) makes use of computer vision to recognize vehicle license plates to further develop security. The customer may pay for a parking slot prior to entering the vehicle in the parking area by using the mobile app. That is, securing a parking lot reservation. The client has the information about the parking location, for example, the real-time free spaces available, and all other applicable data. This article discusses methods and machine learning algorithms for extracting text from car number plates. The algorithm extracts the vehicle license number from the vehicle photo, which is clicked when the ultrasonic sensor detects the vehicle entry and exit. Charges for the vehicle will be calculated on the basis of the entry and exit times of the vehicle.

Automatic Number-Plate Recognition - An image processing and Optical Character Recognition (OCR) technique is employed in the Automatic Number Plate Recognition (ANPR), sometimes referred to as License Plate Recognition (LPR), technology. This is used on pictures or videos to instantly read vehicle license plates and record the location of the vehicle (Innominds 2022). Our Numix video examination suite includes high-level LPR/ANPR technology, which comes in a variety of software versions that are best

suited for various computer vision and OCR scenarios. It provides a versatile Application Programming Interface (API) that guarantees simple reconciliation with various kinds of safety frameworks. ANPR innovation can be effortlessly adjusted to various applications (Innominds 2022). An Automatic Framework for Number Plate Detection was used by Shambharkar et al. (Shambharkar Yash, 2023), where they employed Optical Character Recognition (OCR) and a deep learning approach to detect the number plate of a vehicle.

Fig. 3 Vehicle License/Number Plate Recognition

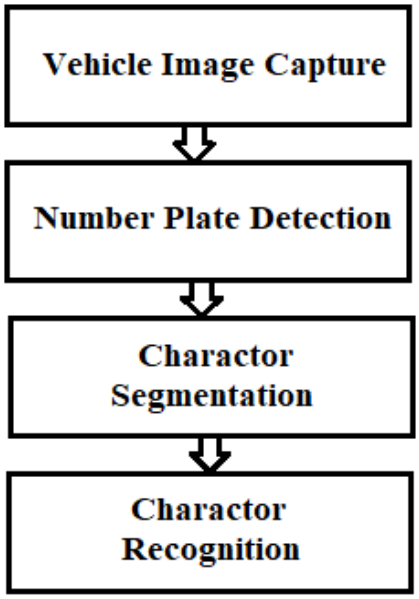

Fig. 4 Conventional ANPR system

Reservation-based Intelligent Parking System– A reservation-based intelligent parking system (SPSR) enables users to reserve available parking spaces in advance. The system maintains a centralized parking database that gathers and stores information related to the driver's identity and the selected parking location. When the time for which the parking slot is booked is about to complete, an automated alert message will be sent to the vehicle driver via the mobile application. The fundamental hindrance is that a few different clients might occupy the saved parking spot; to avoid this, QR scanners are utilized to recognize the client. RFID Scanner-based parking system– The RFID-based parking slot booking allows users to specify their destination and vehicle type using a mobile application. The client's position is regularly updated in the cloud using GPS, and the information about the reserved slot will be saved there. Then the system will determine the quickest route from the user's current location to the parking spot. The moment the client arrives at the parking lot's entrance, RFID (Chechi D 2012) is scanned, and then the person enters the parking space. The cloud server handles billing and payment processing. A noted limitation is that clients will only be able to use parking spaces that are registered in the smart parking system.

Implementation of Wireless Sensor Networks (WSN)— A wireless Sensor Network (WSN) is an infrastructure-less wireless system used to monitor physical and environmental conditions. It is implemented ad hoc using a large number of wireless sensors. This study (Saini S 2017) explains the execution of Wireless Sensor Networks (WSN) with the aid of a server that makes use of XBee Zigbee (Piyare, R 2013) in a smart parking system. The radio module family known as XBee is a trademark of Digi International. The Zigbee Alliance is the owner of the registered trademark Zigbee, a wireless communication protocol. A vehicle that is parked in a parking space can be recognized by the parking system. The goal of this venture is to make it affordable and simple for users to understand. The parking system assists the client with keeping up with information with 90% exactness (Elakya R 2022).

2.1. Existing Smart Parking Systems

There are several intelligent parking systems that are already in operation globally. In this section, a detailed overview of these existing smart parking systems has been presented, which have already been implemented.

- Reservation Based System– The smart parking system proposed in this paper (Corneille N. 2018) provides a complete solution for both parking administrators and users. It provides a reserved parking space feature and identifies reserved users. Clients can, in this manner, explore the closest parking space contingent upon the category of the vehicle. The user has the option to make hourly, daily, weekly, or monthly reservations for parking spaces. The algorithm's objective is to locate the nearest parking space depending on the size of the car. A client's mobile application can be used to make reservations in advance, find the closest parking, and make online payments for the booked parking slot.
- Vision-Based Method- There are two types of monitoring

detection techniques. In the first step, the sum of all incoming and outgoing vehicles is used to calculate the expected number of empty parking spots inside the parking space. The second can be used to direct the vehicle to an open place by keeping track of each individual location's condition. The state of individual parking spaces has been determined using a variety of techniques, including security cameras mounted high up or ultrasonic sensors installed at each site (which would need numerous sensors) (Li L 2017).

- Sensor-Based Method- Sensors are used in this type of detecting technology to find open spots in a parking lot. The appropriate sensor should be chosen based on various characteristics, including size, cost, strength, reliability, and environmental compatibility. There are two types of sensor technologies: invasive and non-intrusive (Nawaz S 2013). Drilling and excavation are needed beneath the road surface in order to install intrusive sensors right on the pavement. Non-intrusive sensors just need to be mounted on the floor or on the ceiling. Non-intrusive sensors are those that use ultrasound (Kianpisheh A 2012). Sound waves between 25 and 50 kHz are emitted by ultrasonic sensors. They inspect and evaluate the status of a parking spot using the reflected energy. The head of the sensor produces ultrasonic waves over an interval of 60 milliseconds. The signals given and received by an ultrasonic vehicle detection sensor are used to determine if a vehicle is present or absent. Another modern framework used sensors to detect the presence of automobiles by using ultrasonic sound waves, and afterward, there was a two-story parking lot that utilized the idea of leaving vehicles on top of one another.

2.2. Smart Parking Challenges

At present, there is a lot of work going on with new technologies, and there are many parking systems that have already been implemented. But there are some challenges faced by these currently existing parking systems. Some of the major challenges are discussed below.

2.2.1. Fake Parking Requests

Performance measures, such as parking space availability, reservation start and end times, parking location, and driver identification, are collected and stored by the system. The system at least applies a time metadata stamp to every piece of data it stores. The user faces a significant difficulty when attempting to book one or more requests simultaneously from one ID because they are only permitted to reserve one parking place at a time. To solve this issue, a queue buffer has been developed that periodically checks incoming queries and compares them with previous ID requests. If any requested ID matches an already-existing ID, it shows that no further parking places are available; hence, the request is instantly denied.

2.2.2. Users' Identity Verification

Due to the fact that people without a reservation may arrive and take someone else's parking space, user identity verification is a serious security risk. The user can access the application under our suggested system and utilize the QR code they were given to confirm their identity. A QR code is sent to the client whenever a parking spot is reserved by the reservation authority. The authority management system's QR code is scanned by the host to identify the user at the parking lot.

2.2.3. Delay in Parking

A parking slot is reserved by a user for a certain period of time. What happens if the customer does not get to the parking spot by the scheduled time? In order to solve this difficulty, customers have been given the opportunity to extend the duration, but they could only do so by 15 minutes. The user must spend more funds to prolong the time.

2.2.4. Timer

When the reservation period is about to end, users must be notified immediately. To address this, SPSR notifies the user in advance at regular intervals. For instance, if the time remaining until the expiry date is merely 30 minutes. When 20 minutes have passed, SPSR will notify the user, and a final notification will be sent after an additional 10 minutes.

Some of the recent work published in the last couple of years, such as (Rafique S. 2023), proposed a high-accuracy, data-driven parking-occupancy detection model using YOLOv5, but their system remains limited to vision-based vehicle identification without user interaction, automation, and payment functionalities.

The work (Elfaki A, 2024) proposed a constraint optimization model for dynamic parking allocation that intelligently prioritizes users based on schedules and organizational constraints. Their work significantly contributes to the theoretical optimization of parking distribution; however, it assumes the prior availability of accurate real-time occupancy data and lacks an integrated sensing or user-interaction layer. Moreover, no hardware implementation, automation, or payment integration is demonstrated, limiting its practical deployment.

As identified in recent studies. (Andrei R 2025) on AI and IoT-enabled smart parking frameworks. Several operational and technological challenges continue to hinder efficient parking management in urban environments. The major issues include

1. Absence of real-time slot visibility- most conventional parking systems still fail to deliver live availability updates to users, leading to inefficient use of space.
2. Congestion due to cruising for parking- drivers spend considerable time searching for weekend slots, contributing to traffic congestion and fuel wastage.

3. Fragmented system architecture- existing models rarely integrate booking navigation and payment into a unified platform.
4. Limited automation- the manual entry and exit process is causing operational issues and is prone to human error.
5. Lack of digital and contactless payment facilities- traditional payment systems reduce convenience and increase costs over time.
6. High infrastructure cost- Reliance on induction loops and overhead infrared sensors raises installation and maintenance expenditure.
7. Poor interoperability with navigation systems - users are often not automatically guided to the allocated or available slots.
8. Environmental inefficiency- successive vehicle idling during the Parking service leads to unnecessary emissions.
9. Inadequate vehicle or authentication and security- absence of reliable identification increases the risk of unauthorized parking.
10. Limited readiness for Smart City integration- many frameworks operate as isolated units without loose coordination.
11. Predominantly conceptual nature of prior research- most work remains theoretical or simulation-based based lacking practical prototype validation.

The review of recent literature and contemporary smart parking implementations clearly indicates that existing systems continue to face multiple operational, technical, and user-level challenges. The persistent absence of real-time slot visibility, inadequate automation, and weak integration between booking, navigation, and payment modules collectively limit the overall efficiency of parking management. Moreover, most models remain conceptually focused, lacking real-world implementation, robust vehicle authentication, and dynamic cost management mechanisms. High infrastructure cost, minimal interoperability, and insufficient readiness for large-scale Smart City integration further restrict their development potential.

The issues summarized above demonstrate that, despite significant advancements in IoT and AI technology, most contemporary smart parking solutions remain either conceptually oriented or Limited in operational functionality. The present work directly addresses these challenges by developing and implementing a fully functional IoT and image processing-based smart parking system that offers real-time slot detection, automated vehicle recognition through OCR, and digital wallet-enabled payment integration. Moreover, by linking the system with Google Maps API, users receive live navigation to the nearest or pre-booked slots, thereby reducing fuel consumption and traffic congestion. The hybrid IoT vision design lowers hardware costs while improving automation reliability, making the system cost-effective and scalable for Smart City deployment. Consequently, this research translates many of the previously identified theoretical challenges into a practical, deployable, and user-centric solution.

3. Proposed Smart Parking System Methodology

The primary goal of the proposed system is to create a new smart parking system that helps vehicles locate nearby parking spots and also helps to get there using the Google Maps API. In addition to that, a digital wallet has also been designed that will help to make the parking experience faster and smoother. The main objective of the proposed work is to create a smart parking system that will help in reducing traffic congestion brought on by cars looking for parking spaces, hence reducing drivers' time wasted, fuel consumption, and air pollution by making the parking experience smoother and faster. These are the features provided by the smart parking system proposed in this paper.

- Get Nearby Parking Areas: This feature will help the user to find the nearby parking areas and choose one according to his/her convenience.
- Live Slots Availability Status: Users can see the availability of available spaces in their chosen car park from anywhere using their smartphone and make decisions accordingly, and there will also be a large screen at the entrance to show the current availability of parking spaces.
- Online Advance Booking: Online Advance Booking is a feature through which you can reserve a parking space for your vehicle in advance using your smartphone. Even if there is no slot available by the time you arrive at your destination, it will be reserved for you.
- Directions to the Parking Area: This is a new feature that helps the user get directions to a certain selected area using our app. This feature will automatically direct you to your reservation.
- Cancellation at Any Time: Allows users to cancel their reservation with a minimum cancellation fee if they have changed their plans.
- Automated Entrance: This feature registers a vehicle entry by its "Vehicle Number" and then automatically opens the gate to enter the car park if slots are available.
- Dynamic Charges: This feature enables dynamic parking charges instead of traditional fixed charges, where a person has to pay the full amount for 1 hour, even if the vehicle has been parked for 10 minutes.
- Easy, Flexible, and Fast payment: A digital wallet has been designed to make payments faster and smoother. Users can make payments with their digital wallet, Online payment using Paytm, Google Pay, or Phone Pay, or choose to pay in cash.
- Smart Automated Exit: If the payment is successful, the system will send an instruction to open the exit gate, and it will automatically open the exit gate and allow the vehicle to exit.

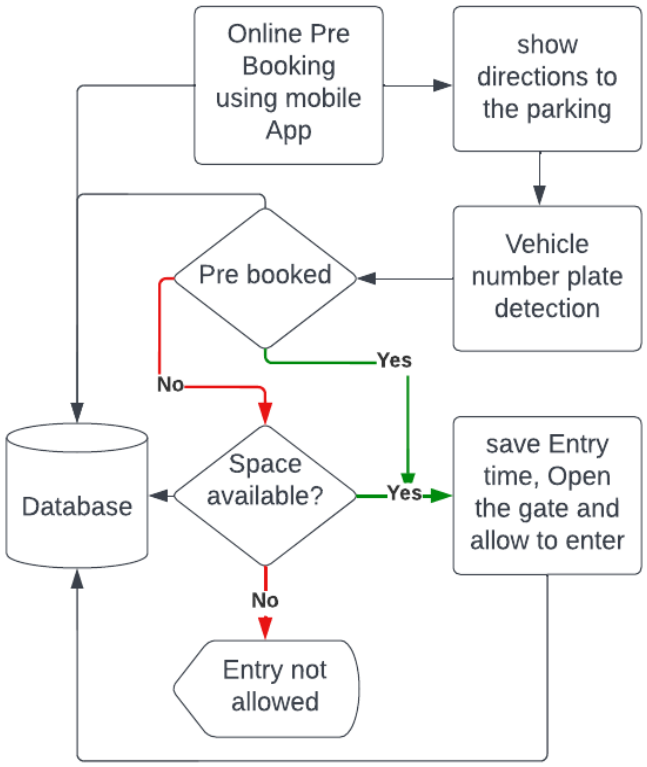

Fig. 5 Flow diagram for pre-booking and entrance

The proposed smart parking system integrates three key components: IoT-based sensing and communication, cloud data management, and image processing-based vehicle identification to ensure automation scalability and user convenience.

3.1. IoT Architecture

The IoT framework follows a three-layer architecture consisting of perception, network, and application layers.

- The perception layer includes ultrasonic and infrared sensors installed at each marking spot to detect vehicle presence and transmit data through microcontroller units.
- The network layer handles data transmission using Wi-Fi modules connected to a centralized Firebase Cloud database, as well as real-time monitoring and synchronization with the Android mobile application.
- The application layer manages user interaction, including slot booking, payment processing, and navigation through a Google Maps API.

The IoT devices continuously upload slot Occupancy data to the cloud, which updates every 5 seconds. This design ensures that the system can manage multiple parking areas simultaneously and maintain real-time accuracy within ±3 seconds of detection delay.

3.2. Image Processing and OCR Algorithms

At the parking entry and exit point, cameras capture vehicle number plates automatically when a vehicle triggers the ultrasonic sensor. The image data undergoes pre-processing using grayscale conversion, Gaussian filtering, and edge detection (Canny algorithm) to isolate the region of interest (the number plate area), as shown in Figure 16. The segmented plate is then processed through an Optical Character Recognition (OCR) module built using Tessract OCR, which extracts the alphanumeric registration number. This number is matched against the user registration details in the database to verify parking authorization and calculate dynamic billing based on entry/exit time stamps.

3.3. System Integration and Flow

When A user books a parking slot through the Android app, the request is authenticated through the Firebase Cloud. A unique reservation ID and QR code are generated for verification at the parking gate. Upon entry, the IoT controller validates the booking, logs the time, and activates the OCR module. The same process occurs at the exit to finalise billing and update slot availability.

The flow diagram for the Entrance process for the proposed system is shown in Figure 5. As you can see, the first user pre-books a parking space for their vehicle; then,

directions to the parking area will be shown in the mobile application. As shown in the flow diagram (refer to Figure 5), at the time a user enters the entrance of the parking area, vehicle license plates will be detected, and vehicle license numbers will be extracted with the help of Image processing and Optical Character Recognition (OCR) techniques. Now the system will check the database if pre-booking exists for this vehicle, as shown in the figure (refer to Figure 5).

If the pre-booking exists, then the gate will be opened, and the timer for a particular vehicle starts. In case pre-booking does not exist, vehicles will only be allowed if extra space is available. Figure 6 shows the flowchart for the exit process from the parking area. As the vehicle reaches the exit gate, the vehicle number will be extracted using image processing and OCR techniques (Samantaray M 2022), the same as at the time of entrance.

Now the system will search for the entry time of the vehicle and calculate charges accordingly. As soon as the payment is done, the exit gate will be opened, and the vehicle will be allowed to exit.

4. Implementation, Results, and Discussion

The smart parking system proposed in this system contains a mobile application for users. This application can be used to see the live availability of the parking slots. Users can pre-book a parking slot and will also get directions to the parking area using the Google Maps API. At each parking area, 2 cameras and 2 ultrasonic sensors at the entrance and the exit gate, and a computer system to communicate with the database. For the development of mobile applications, the Java language is used, for the vehicle license number extraction from vehicle image, OpenCV and OCR techniques (Samantaray M 2022) are used with Python.

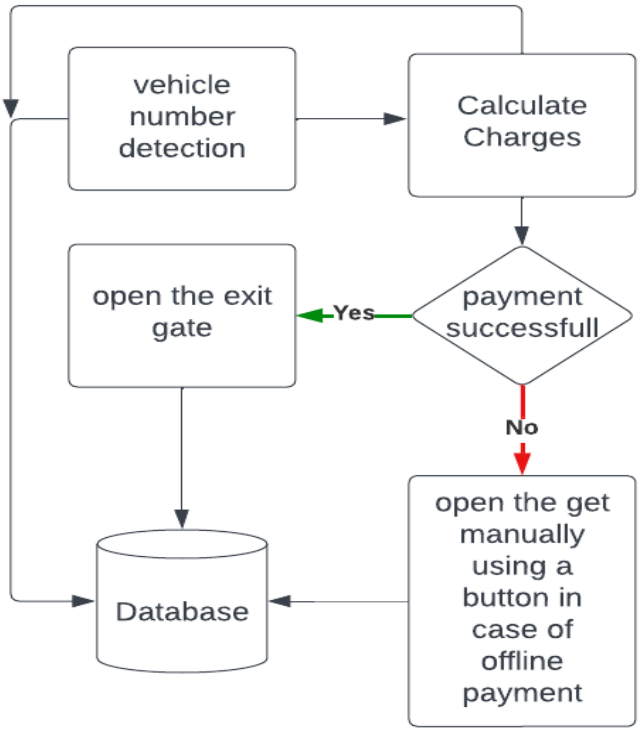

Fig. 6 Flow diagram for exit from parking

4.1. Implementation of Pre-Booking

Pre-booking is the concept in which a user reserves a parking slot in advance for a particular time. The proposed work includes the online Booking of a parking slot in advance for a particular time at the chosen parking area, so that at the time the user reaches the parking area, there is space reserved for his vehicle (refer to Figure 7). This project also helps to find parking areas nearby and helps to reach them using Google Maps.

4.2. Directions to the Parking Area

This feature helps the user get to the parking space by showing directions to the parking area he has chosen from his current location. For this, the Google Maps API is used in the mobile application.

As shown in the figure (refer to Figure 8), if a person is at “Gajjar Bhawan” and he/she chooses the “Prodigy Club Parking” to park his/her vehicle, The system will show the

most convenient routes to the user to go to the chosen parking area with the help of google maps API and user may now select any of these routes based on convenience. This will help the user to locate a parking lot nearby and to get there, without wasting extra fuel and time in searching for a parking area and asking for the route to get there.

4.3. Automated Entrance

Once the user reaches the entrance gate of the parking area, an ultrasonic sensor detects the vehicle (refer to Figure 9) and sends a signal to the camera mounted at the entrance, which will take the image of the vehicle and then extract the vehicle/license plate number with the help of Image Processing.

The proposed system identifies the number plate in the images and then reads the vehicle number, and then finds in the database that any slot is booked with this vehicle (refer to Figure 10).

Case 1: Yes, the Parking slot is pre-booked for this vehicle number: Start the time for a particular vehicle, and open the entrance.
Case 2: No- No pre-booking for this vehicle number exists: Check if a parking space is available for parking.
Subcase 1: Yes: Start the time for a particular vehicle and open the entrance.
Subcase 2: No: A TV display at the entrance gate shows that the parking area is full and no slots are available currently.

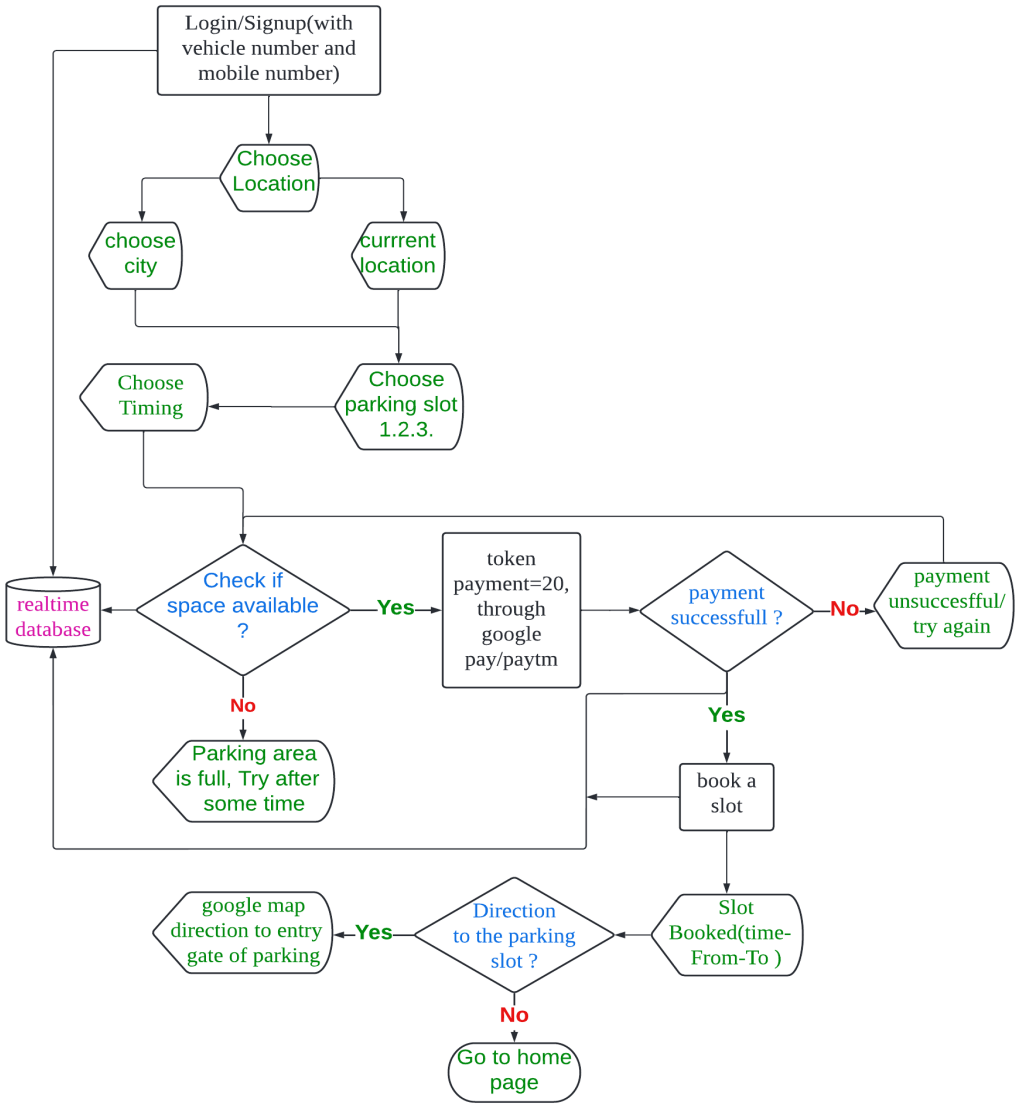

Fig. 7 Block diagram for pre-booking

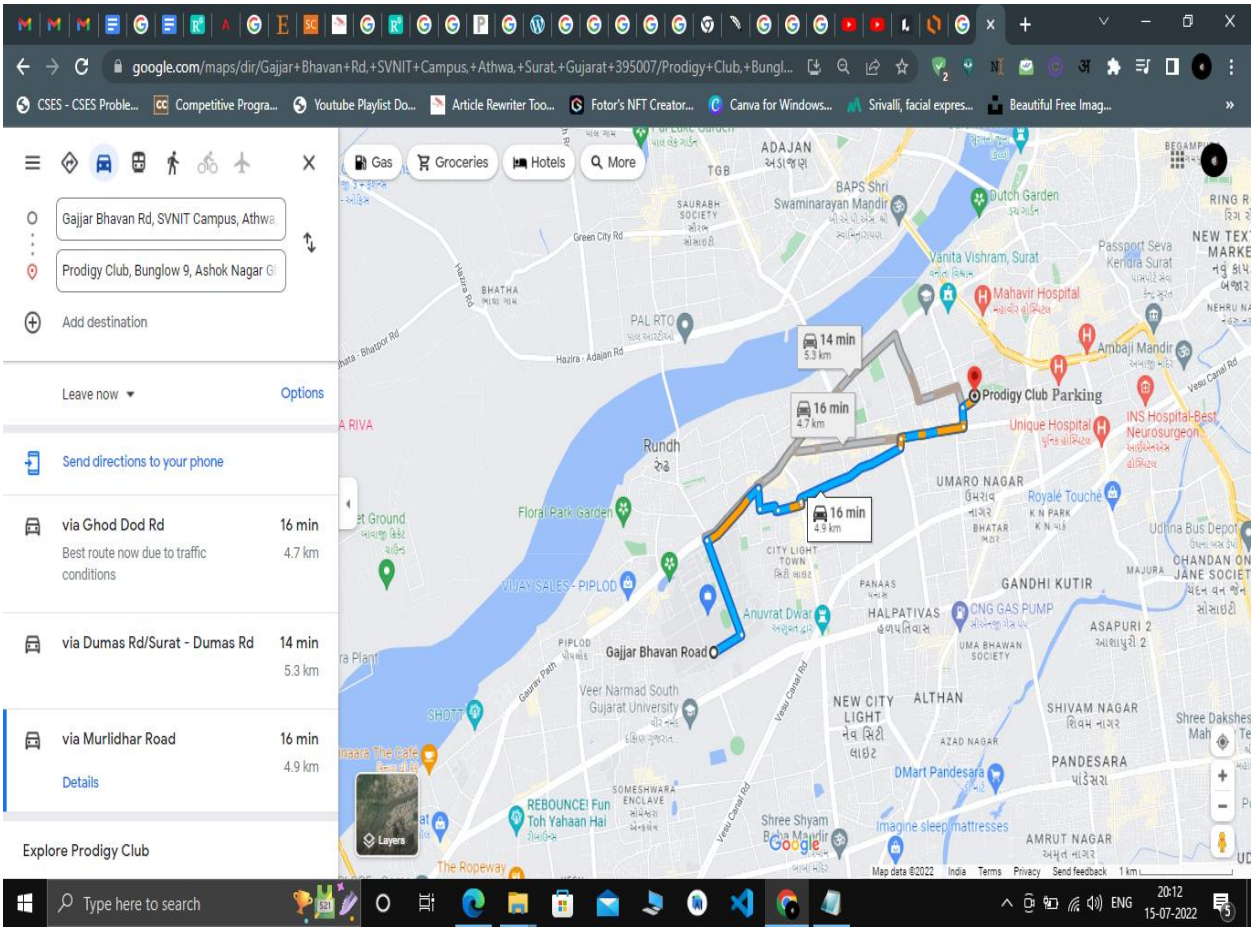

Fig. 8 Direction to the chosen parking Area

Fig. 9 Automated entrance and exit

4.4. Automated Exit

Once the payment is done, the system will send an automated message that the payment is successful, and the exit gate will automatically open or can be opened manually by the parking assistant by pressing a button in case of offline payment or emergency situations. By calculating the number of automobiles that arrive and depart, this system, which monitors the parking lot in real-time, determines how many parking spaces are empty, which takes a lot of time and work.

The target of this work is to connect the parking spaces with the globe using IoT and the cloud, and assist the user with finding the closest and least expensive parking lot. Using mobile applications and some electronic components. One of the Important parts of this project is to capture a photo of the vehicle and detect the number plate using image processing, and then to extract the vehicle number using OpenCV and OCR technology (Samantaray M 2022).

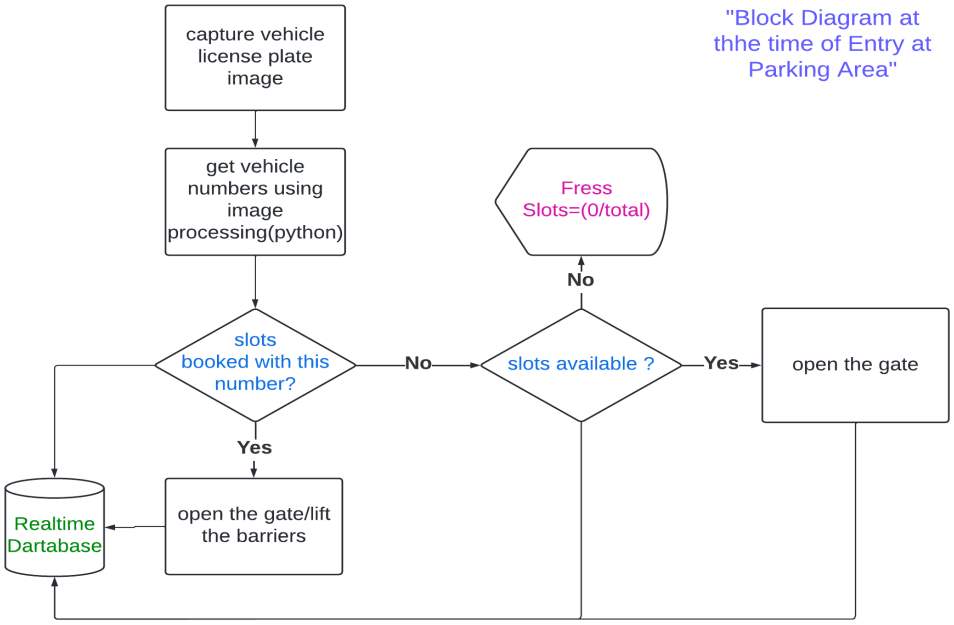

Fig. 10 Block diagram for entrance

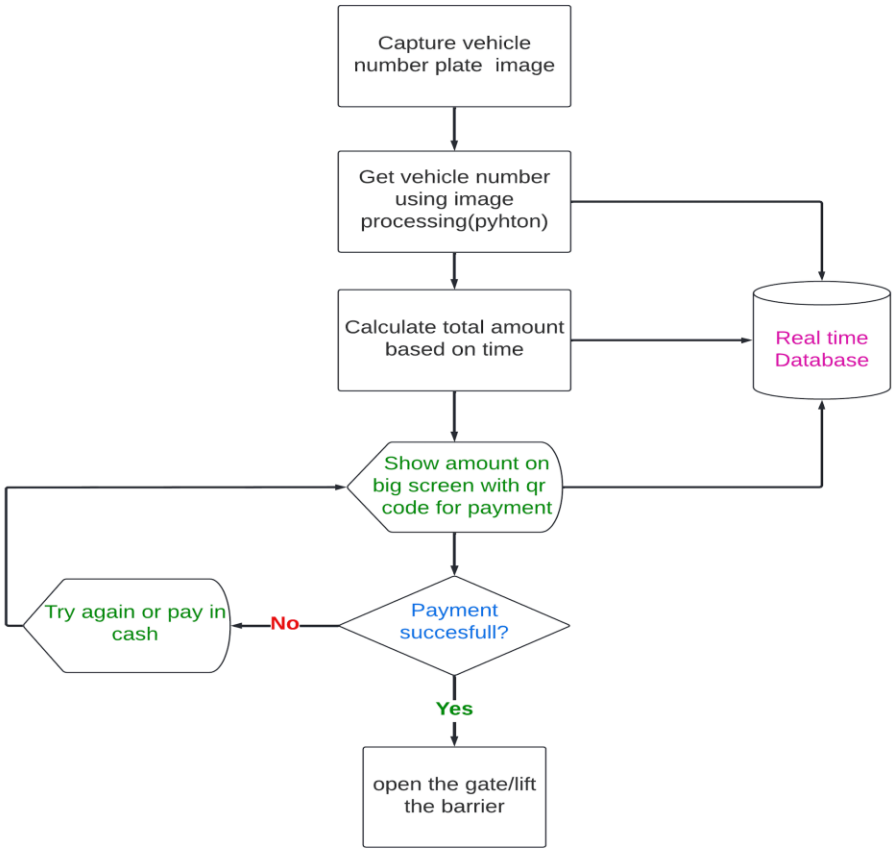

Fig. 11 Block diagram for dynamic payment and exit

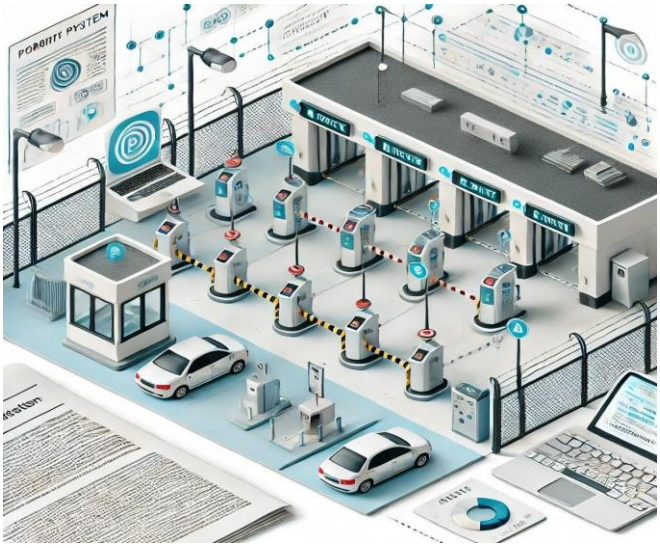

Fig. 12 Smart parking automated entrance and exit

Fig. 13 Input vehicle image for license plate detection

Fig. 14 Image converted to a black and white image to improve the efficiency of the Canny algorithm (Sekehravani E. 2020) for edge detection.

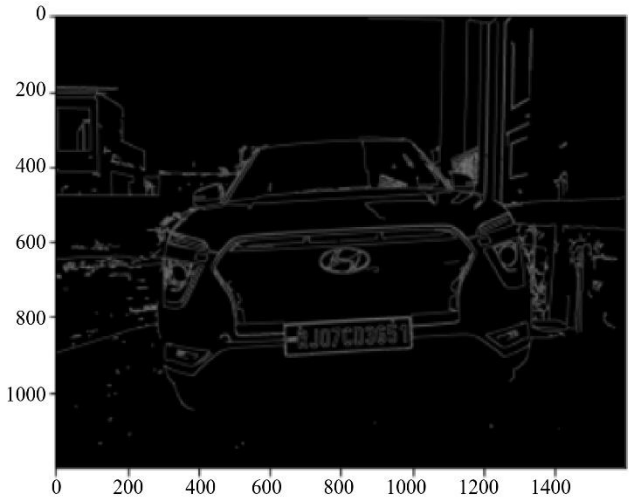

Fig. 15 Image after applying Canny edge detection (Sekehravani E. 2020)

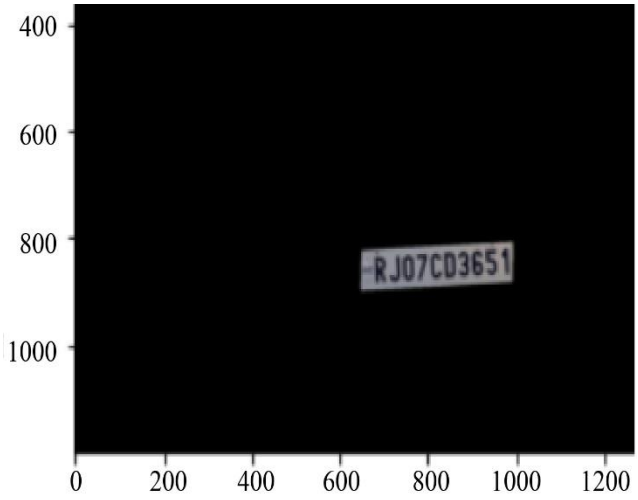

Fig. 16 Image after locating the number plate in the processed image using contour detection (Win N 2019)

Fig. 17 Cropped image of vehicle license plate

Fig. 18 Final image after extracting vehicle number using OCR technology (Samantaray M 2022)

As can be seen in the above figures, the system first takes the input image (refer to Figure 13) and makes it black and white (refer to Figure 14) to improve the efficiency of the Canny algorithm (Sekehravani E. 2020).

Then it removes the noise from the image using filtering techniques **(**Win N 2019**)**. Now the system applies the Canny algorithm for edge detection, as shown in the figure (refer to Figure 15).

Now, with the help of contour detection (Gong X., 2018; Hossen M., 2022) using OpenCV, the system detects the vehicle number plate location and crops the number plate (refer to Figures 15 and 16).

With the help of OpenCV and OCR techniques (Samantaray M 2022), the system extracts the text (vehicle license number) from the image (refer to Figure 18) with a high accuracy (depending on the image quality). Testing with good-quality images gives accuracy as high as 98 to 99%.

To evaluate the performance of the proposed smart parking system, a pilot implementation was conducted in a control environment with 50 parking slots and an average of 120 vehicles per day. The results were compared against traditional manual parking management and two existing smart systems reported in the literature (Corneille, 2018; Elakya, 2022)

4.4.1. Time Efficiency

The proposed system significantly reduced the average time spent searching for an available parking slot. In the manual parking setup, the driver spent an average of 8.2 minutes locating a free slot. In the proposed IoT system, the average search time was reduced to 2.4 minutes, representing a 70.7% reduction in the parking search duration. This improvement was primarily due to real-time slot detection, pre-booking operations, and Google Maps navigation integrated within the mobile application.

4.4.2. Fuel Consumption

Based on average vehicle idling time data (0.8 litres/hour for compact cars), the proposal system reduced unnecessary idling by an estimated 65%, leading to an average fuel saving of 35-40 ml per vehicle per parking session. Cumulatively, this results in a reduction of approximately 4.2Ltr of fuel per day across 120 vehicles, contributing to both economic and environmental benefits.

4.4.3. System Accuracy and Reliability

IoT sensors and OCR modules were tested for performance under varying light and network conditions. The slot detection accuracy achieved 96.5%, while the licence plate recognition accuracy was 98% during daylight and 87.5% under low-light conditions. Overall, this work will help in managing parking in cities and help the user make the parking experience smoother and faster.

Table 1. Comparison of proposed smart parking systems with existing systems based on the services provided

Reference	Parking Reservation	Security	Vehicle Guidance	online Payment	Gate Management	Parking Supervision	Lot Retrieval	Digital wallet	Dynamic Charges	Any Time Cancellation	Automated Entry and Exit
(Sai V 2013)						Y					
(Suryady Z.`2014)	y	y			y	y	y				
(Karbab M 2015)	y	y	y		y	y	y				
(Amato G. 2016)		y				y	y				
(Thangam E. 2018)	y	y		y							
(Cynthia, C 2018)	y		y			y					
Proposed Smart Parking System.	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y

Table 2. Comparative analysis of smart parking system

Parameter	(Rafique S, 2023)	(Elfaki A, 2024)	Proposed Smart Parking System
Type of Work	Experimental (deep-learning-based detection)	Theoretical/mathematical optimization model	Prototype implementation (IoT + image processing + mobile app)
Primary Aim	High-speed, high-accuracy vehicle detection and slot classification	Optimal allocation of parking spaces under operational constraints	Complete parking-management workflow: slot detection, booking, automation, payment
Core Technologies	YOLOv5 object detection, transfer learning, PKLot dataset	Constraint optimization, ad-hoc scheduling algorithm	IoT sensors (ultrasonic), OpenCV + OCR, Google Maps API, Android app, digital wallet
System Scope	Focused only on occupancy detection	Focused only on allocation logic	Full end-to-end system from detection → allocation → payment
User Interface	None (algorithmic only)	None (algorithmic only)	Implemented an Android mobile app with booking, navigation, and payment
Automation / Hardware	Software-only model	Algorithmic model (no sensors)	IoT-controlled gate automation and live slot display
Vehicle Authentication	Not addressed	Not addressed	Implemented OCR-based

			license-plate recognition
Payment Mechanism	Not included	Not included	Implemented digital wallet and dynamic, time-based pricing
Navigation Integration	Absent	Absent	Implemented through the Google Maps API for route guidance
Data Handling	Offline vision datasets	Simulated data (benchmark)	Real-time IoT data + camera input via cloud server
Validation	Accuracy ≈ 99.5 % (PKLot)	Allocation efficiency metrics only	Functional prototype tested; OCR accuracy ≈ 98–99 %
Scalability	Dependent on camera infrastructure	Scalable in theory only	Cloud-based IoT architecture supporting multi-site expansion
Main Limitation	Lacks automation, integration, and user-level interaction	No sensing, prototype, or payment integration	Provides full implementation and tested automation features

Table 3. Issues highlighted in (Andrei R, 2025) and addressed in the proposed work

Issues Highlighted in (Andrei R 2025)	Proposed Solution
Absence of real-time slot visibility- most conventional parking systems still fail to deliver live availability updates to users, leading to inefficient use of space	Implemented via IoT sensors and image-processing modules that continuously update parking-slot status in real time.
Congestion due to cruising for parking- drivers spend considerable time searching for weekend slots, contributing to traffic congestion and fuel wastage	Advance booking and live navigation using the Google Maps API reduce cruising time by guiding drivers directly to available parking.
Inadequate vehicle or authentication and security- absence of reliable identification increases the risk of unauthorized parking	Dynamic slot allocation and real-time tracking optimize utilization by ensuring every available space is visible to users.
Fragmented system architecture- existing models rarely integrate booking navigation and payment into a unified platform.	Developed an Android mobile app integrating slot booking, live status, route navigation, payment, and cancellation.
Limited automation- the manual entry and exit process is causing operational Lily and is prone to human error	Fully automated entry/exit using OCR-based vehicle number detection and IoT-controlled gates.
Lack of digital and contactless payment facilities- traditional payment systems reduce convenience and increase costs over time	Implemented digital-wallet and online payment systems for contactless, quick transactions.
High infrastructure cost- Reliance on induction loops and overhead infrared sensors raises installation and maintenance expenditure	Used a hybrid model combining low-cost IoT sensors and existing camera infrastructure to make the system cost-efficient and scalable.
Poor interoperability with navigation systems - users are often not automatically guided to the allocated or available slots.	Seamless integration with the Google Maps API automatically directs users to the nearest or pre-booked parking space.
Environmental inefficiency- successive vehicle idling during the Parking service leads to unnecessary emissions.	By reducing cruising time and automating slot allocation, your system directly reduces fuel consumption and emissions.
Inadequate vehicle or authentication and security- absence of reliable identification increases the risk of unauthorized parking.	License plate recognition (OCR) ensures every vehicle is verified upon entry and exit, adding security and traceability.
Limited readiness for Smart City integration- many frameworks operate as isolated units without loose coordination	Cloud-connected IoT architecture supports multiple parking sites, aligning with smart-city integration.
Predominantly conceptual nature of prior research- most work remains theoretical or simulation-based, lacking practical prototype validation.	Real-world prototype implementation, validated through practical experiments and performance testing.

As listed in Table 1, the proposed smart parking system not only provides all the services of existing parking systems but also offers some unique services, such as a digital wallet facility, an anytime cancellation facility, and a human-less automatic entry and exit facility.

As mentioned in Table 2, the comparison highlights that earlier studies focused on individual aspects such as vehicle detection and slot detection while lacking real-time implementation and automation. In contrast, the proposed IoT and image-processing-based system integrates detection, booking, payment, and gate control into a complete deployable framework.

Table 3 shows all the issues listed in the literature review section (Andrei R, 2025) and how these have been addressed in the proposed work.

5. Limitations

During experimental implementation, the following limitations were observed.

- The camera's sensitivity to low-light conditions occasionally reduced OCR accuracy.
- Wi-Fi dependency leading to brief data-sync delays when network coverage was weak
- The range of ultrasonic sensors was limited to approximately 3 meters, affecting detection accuracy in a large, open parking area.

6. Conclusion and Future Research Directions

The proposed IoT and image processing based smart parking system presents a practical solution to urban traffic congestion caused by random Search for parking space by enabling users to locate and pre-book nearby parking slots and guiding them through the fastest and shortest route by a Google Maps API system reduces unnecessary cruising by 65%, thus fuel saving by approximately 35-40ml per vehicle, and reduction in parking search time by more than 70% when tested in controlled environment. This automation minimises human involvement and simplifies the overall parking experience while contributing to fuel conservation and environmental sustainability. The implementation demonstrates that integrating IoT sensors, image processing, and cloud-based data synchronisation can significantly improve the efficiency of city parking operations. In future extensions, this work can be extended to integrate LoRa communication for extending range and adaptive thresholding algorithms to enhance number plate recognition under varying lighting conditions to mitigate the limitations mentioned in the previous section. The system can also be enhanced with real-time monitoring of parked vehicles, allowing users to view their car's exact position within the parking facility. Additional functionalities, such as indoor navigation to the park vehicle, dynamic pricing, and integration with smart city traffic management systems, can further improve scalability and user convenience. Overall, the presented work established a strong foundation for next-generation smart parking solutions aimed at reducing congestion, saving energy, and enhancing urban mobility.

Ethical and Privacy Considerations

The implementation of IoT and image processing-based systems for smart parking must adhere to ethical standards and data privacy regulations to ensure user trust and legal compliance. In the proposed system, particular attention has been given to protecting users' data, maintaining transparency, and ensuring responsible information handling. All communication between IoT devices, cloud Servers, and mobile applications is secured through an encrypted channel to prevent unauthorised access. The system follows the principle of data minimization, collecting only essential information such as vehicle number and parking slot details necessary for the operational functionality. Personally identifiable information, including user and payment data, is managed through secure, compliant third-party gateways that meet GDPR and IoT data protection standards. Moreover, users are informed about data use policies within the mobile application and can consent to or withdraw participation at any stage. This ethical approach ensures that the proposed smart parking system not only enhances urban mobility but also respects user privacy and others to established IoT governance frameworks.

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