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Smart Parking Revolution: Integrating AI and IoT for Autonomous Management

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Abstract: **-** As urbanization increases, effective parking solutions are vital for managing space constraints and reducing traffic congestion. Smart parking systems that integrate Artificial Intelligence (AI) and the Internet of Things (IoT) enhance user experience, optimize space utilization, and provide real-time updates. These systems also support environmental sustainability by minimizing fuel consumption and emissions. However, existing solutions often suffer from limited scalability, poor real-time data handling, and inadequate IoT integration. Additionally, Automatic License Plate Recognition (ALPR) systems frequently struggle with accuracy in varying environmental conditions. To address these issues, this project proposes an Autonomous Parking Management System that combines AI and IoT technologies. The system dynamically allocates parking spaces using AI for accurate vehicle identification and IoT for real-time space monitoring. A camera-based ALPR module enables quick and precise license plate recognition. Users can register their vehicle, reserve slots, and receive status notifications through a user-friendly mobile application.

Keywords*: Smart Parking Systems, Artificial Intelligence, Internet of Things, Automatic License Plate Recognition*

1. Introduction

Cities around the world are dealing with a number of issues related to the growing number of vehicles on the road as urbanization picks up speed. The increasing demand for parking spaces is one of the most urgent problems facing contemporary cities. The International Transport Forum estimates that drivers looking for parking are responsible for up to 30% of city traffic congestion. In addition to wasting important time, this increases emissions, fuel consumption, and environmental pollution. Parking spots are scarce and frequently underutilized in many large cities, which worsens traffic and lowers the standard of living for locals. More effective, environmentally friendly, and technologically advanced parking solutions have become necessary as a result of the sharp rise in car ownership and the lack of available parking spaces in cities. The demands of an expanding urban population can no longer be satisfied by antiquated ticketing systems or manual space finding, two traditional parking methods. In order to maximize parking utilization, lessen traffic, and enhance the overall urban mobility experience, new solutions are needed as cities grow and parking management becomes more complex. Smart parking systems have surfaced as a potential remedy for these issues. Smart parking systems have the potential to revolutionize the management and use of parking spaces in urban areas by combining artificial intelligence (AI), the Internet of Things (IoT), and sensor networks. These systems provide smooth communication between users, parking spots, and management platforms, as well as real-time parking space monitoring and automated vehicle identification.

Even though modern smart parking solutions are a big step up from conventional parking techniques, a number of important issues still need to be resolved before these systems can be fully utilized. One significant problem is integrating cutting-edge IoT technologies, which are necessary for communication, scalability, and real-time data processing. Numerous current systems have sluggish data updates or are devoid of the infrastructure required to effectively manage extensive parking operations. Because of this, users might still have trouble locating open spaces, particularly during busy times, and the system as a whole might find it challenging to grow in expanding urban settings. The effectiveness of Automatic License Plate Recognition (ALPR) systems, which are frequently used for vehicle identification and authentication in smart parking, is another significant challenge. Even though ALPR is now a fundamental component of contemporary parking systems, variables like weather, lighting, and camera feed quality can have a big influence on how accurate it is. These restrictions may cause license plates to be misidentified or not recognized, which could cause delays and mistakes during the parking process.

Furthermore, inefficient use of parking spots is frequently the result of existing systems lack of dynamic parking space allocation algorithms. Conventional parking management systems usually allocate spots based on a first-come, first-served basis, disregarding variables like user preferences, anticipated duration of stay, or proximity to exits. Because drivers may end up parking in spots that could be better used by others, this inefficient allocation results in wasted space and a bad user experience.

By creating an AI and IoT-based Autonomous Parking Management System that combines cutting-edge AI technologies, IoT infrastructure, and dynamic parking space allocation algorithms, this project aims to fill the gaps in current smart parking systems. The main goal of this project is to develop a parking management system that is more intelligent, scalable, and sustainable in order to successfully manage the intricate demands of urban parking. Improving the precision and effectiveness of Automatic License Plate Recognition (ALPR) technology is the primary driving force. Enhancing the functionality of smart parking systems requires the ability to recognize license plates accurately, even in difficult environmental circumstances. This project intends to guarantee quicker and more accurate vehicle identification while lowering errors and delays by creating a more robust and dependable AI-based ALPR model. Resolving the issues with the existing IoT-based parking systems is the second driving force. The inability of many current solutions to process data in real-time restricts their capacity to scale and handle a high volume of vehicles. This project intends to provide real-time parking space monitoring through a more sophisticated IoT framework, with prompt and dependable updates that users can access through a mobile application. Communication between parking sensors, cameras, and the central management platform will be smooth thanks to the integration of IoT devices with a camera-based license plate recognition system.

2. Related work

The development of autonomous parking management systems using AI and the IoT is examined in this review of the literature. The development of IoT-based parking technologies, license plate recognition (LPR), smart parking systems (SPS), and their application in smart city settings are all critically examined. The benefits and drawbacks of these systems are emphasized, along with the developments in technology that have enhanced their usability, scalability, and efficiency. Chowdhury et al. [1] emphasize how the problem of effectively allocating parking has become more difficult due to rapid urbanization, which has led to more traffic in city centers. In order to maximize parking space utilization and minimize search time and traffic accumulation, their study outlines important technological interventions, such as sensor networks, real-time data analytics, and intelligent decision-making algorithms. Tripathi et al. [2] examine Automatic Number Plate Recognition (ANPR) systems, which extract vehicle information from photos using optical character recognition. These systems are utilized all over the world for surveillance, toll collection, and traffic enforcement. ANPR systems with infrared lighting can function in a variety of lighting scenarios and have the ability to store driver and vehicle data for improved surveillance. Chauhan et al. [3] concentrate on image detection and recognition using deep learning, specifically Convolutional Neural Networks (CNNs). They assess CNN models' performance in identifying license plates and vehicle features using datasets such as MNIST and CIFAR-10, demonstrating their high accuracy and potential for scalable applications.

Sharma et al. [4] highlight how object detection is becoming more and more important in areas like surveillance and driverless cars. Deep neural network-powered object detection algorithms improve system intelligence and safety by recognizing and categorizing vehicles in intricate scenes. Shrimal et al. [5] talk about how AI is having a disruptive effect on the automotive industry, where its incorporation has produced safer and more effective automobiles. By combining AI and IoT, smart cities can make data-driven decisions in real time, improving parking, traffic flow, and emergency response times, all of which promote sustainable urban growth. Prasetyo et al. [6] chart the development of parking systems from manual techniques to increasingly complex image processing methods. They suggest a system that improves the accuracy of identifying individual cars by utilizing computer vision techniques like OCR and the SURF algorithm to detect vehicle features even when vehicles have similar colors and shapes. Perković et al. [7] highlight the importance of LPWA technologies (LoRa, Sigfox, NB-IoT) and low-power sensors in smart parking infrastructure. The viability of IoT-based parking sensors in practical deployments is increased by their analysis of sensor performance and energy consumption, which shows that LoRa-based systems provide the best battery usage. A scalable architecture for Intelligent Transportation Systems

(ITS) is presented by Alam et al. [8]. It disperses intelligence via Internet of Things gateways and decentralizes decision-making. This method improves the system's flexibility and reactivity in handling parking and traffic issues in cities. For real-time parking management, Luque-Vega et al. [9] introduce SPIN-V, a smart vehicle presence sensor that is connected to a monitoring center and a mobile app. In order to give dependable parking space status updates and support better urban transportation solutions, the system makes use of distance sensors, cameras, and computer technology. For real-time parking occupancy categorization, Nyambal et al. [10] suggest a CNN-based model that makes use of Nvidia DiGITS and the Caffe framework. Their system, which was trained on datasets using the AlexNet and LeNet architectures, analyzes parking lot video streams and uses bounding boxes to estimate the availability of space.

The growing urban population and vehicle density make the shortcomings of traditional parking facilities more apparent. Conventional parking techniques are expensive, time-consuming, and ineffective. IoT devices like magnetometers and ultrasonic sensors are frequently used in enclosed locations, but their usefulness in open parking lots is still restricted. Lighting and other environmental factors still make accurate space sensing difficult. For real-time open space parking detection, sophisticated methods such as deep learning algorithms and multi-agent systems have been suggested. Techniques like Anisotropic Diffusion Gaussian Filtering (ADGF) and Grey Level Co-occurrence Matrix (GLCM) have the potential to improve image-based vehicle detection. Research on expanding these smart parking devices to open spaces is still lacking. Furthermore, the reliance on centralized systems raises concerns over data privacy and security. Blockchain has been proposed as a potential solution to decentralize control and enhance transparency, though its scalability and integration into existing parking systems are still under investigation. While smart parking systems are expected to reduce fuel consumption and greenhouse gas emissions, there is a paucity of research quantifying these environmental benefits. Future studies should focus on evaluating the carbon footprint of smart parking technologies in comparison with conventional parking solutions, improving the robustness of detection algorithms in dynamic outdoor conditions, and developing secure, decentralized platforms for scalable deployment.

3. Methodology

For smooth real-time parking space management, the Autonomous Parking Management System (APMS) methodology combines AI and the IoT. Two AI models are used by the system to detect parking spaces and identify vehicles. While the second AI model, which is installed with CCTV cameras, finds open parking spaces, the first AI model is utilized for License Plate Recognition (LPR) at the entrance. These technologies guarantee an effective, self-sufficient, and user-friendly parking solution when paired with IoT sensors and a mobile application. As seen in Figure 1, the methodology is broken down into the following main sections: System Architecture, AI Model Development, IoT Integration, and App Development for User Interaction.

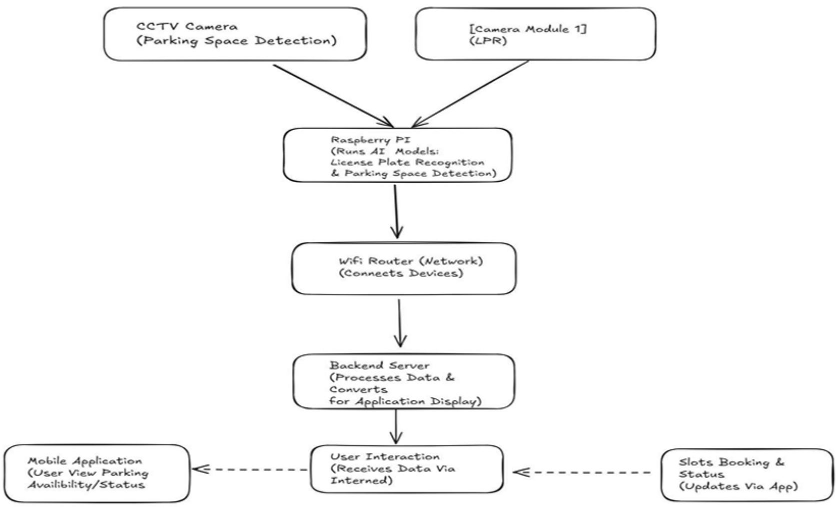

Figure 1 System Layout

3.1 System architecture

The Autonomous Parking Management System's System Architecture is made up of a number of essential parts, each of which is vital to the system's operation. Based on a client-server architecture, the user can access data from IoT sensors and AI models through a mobile application that is sent to a cloud server. The system architecture is broken down in Figure 2 below.

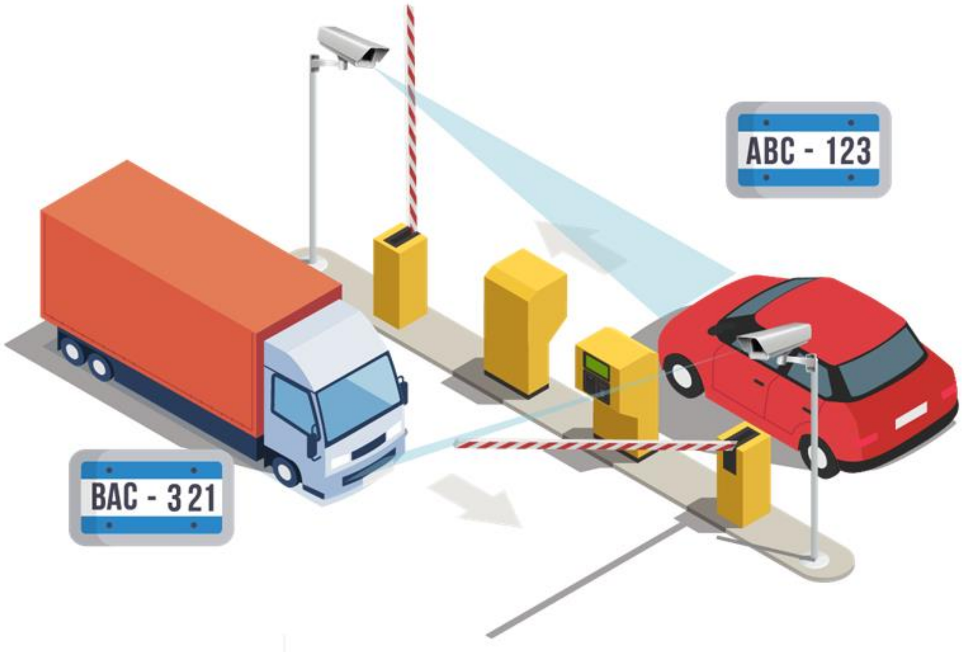

Figure 2 Camera Module LPR on Vehicle Entry

Important elements include: IoT sensors: these sensors are to determine space availability and keep an eye on environmental conditions, ultrasonic sensors for occupancy detection and environmental sensors are positioned throughout the parking lot.

License Plate Recognition (LPR): This model, which is positioned at the entrance, automatically reads incoming cars license plates for access control and identification.

Parking Slot Detection Model: This model analyzes real-time images from CCTV cameras positioned throughout the parking lot to identify open parking spots.

Cloud Server: The cloud server collects, processes, and transmits real-time updates to the mobile app from all IoT devices and AI models. Additionally, the server manages reservation management, parking history, and user transaction data storage and retrieval.

Mobile Application: The app functions as the user interface and offers navigation to available parking slots, real-time parking space availability, reservation options, and payment features.

3.2 AI model development

As cars come and go from the parking lot, the AI model called License Plate Recognition is in charge of reading and recognizing their license plates. This model is positioned at the parking lot's entrance. OCR (Optical Character Recognition) was selected due to its effectiveness in identifying text in images, including a wide range of font styles and formats. Utilizing YOLO (You Only Look Once) to locate and identify license plates in pictures or real-time video streams. Gathered a variety of license plate photos from different areas and in a range of weather, angle, and day/night conditions. Bounding boxes for plates and text annotations for OCR training were used to label the dataset.

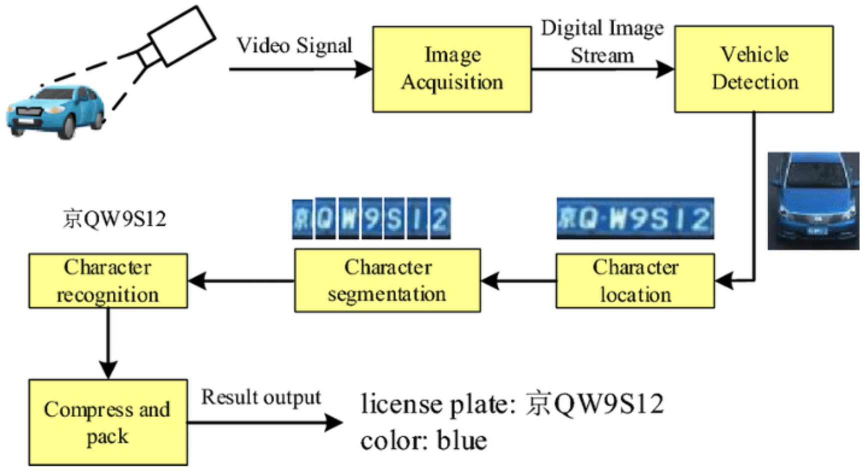

Figure 3 AI License Plate Recognition Pipeline

The second AI model uses CCTV cameras positioned all over the parking lot to find open spots. To find empty spaces, the model analyzes live video footage. CCTV cameras continuously record footage from the parking lot, giving analysts access to real-time images. Gathered aerial and ground-level parking lot photos in various weather conditions (rain, night, and day) with marked and unmarked slots.

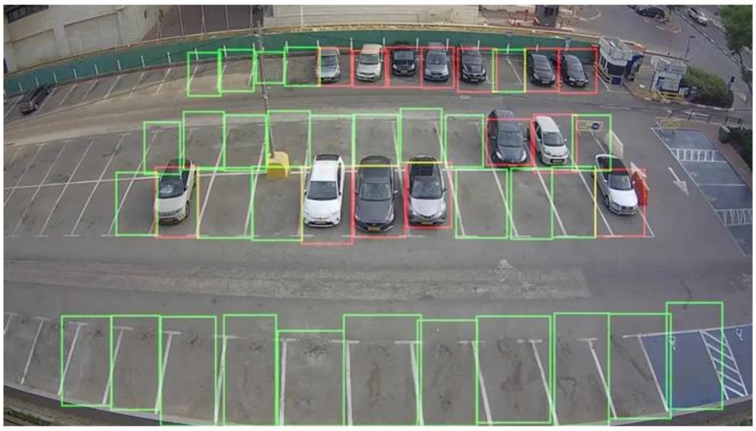

Figure 4 AI Model Parking Slot Detection

Images that have been annotated with labels for "occupied" and "vacant" states and bounding boxes showing the boundaries of the slots. To verify the detection accuracy, it was tested on both live and recorded parking lot feeds. Measured the model's performance with F1 score, precision, and recall. The pipeline of the license plate recognition model can be inferred from Figure 3 above. It is comparable to the LPR model and image preprocessing techniques. Similar to the LPR model, image preprocessing techniques are applied to ensure the video feeds are clear and suitable for analysis. Using Convolutional Neural Networks (CNNs), the model is trained to identify vehicles in the parking spaces as shown in Figure 4 and distinguish between occupied and free slots. YOLO algorithm used for fast object detection. The model processes the camera feed and detects vacant spaces by analyzing the absence of vehicles in predefined parking spots. Overcame issues with irregularly marked slots by training with diverse data samples. Addressed overlapping vehicles by enhancing the dataset with edge-case scenarios. The camera module captures a live video feed of the parking area. Frames are passed through the model deployed to identify parking slot status. Detected data is transmitted to the backend server for further processing and user notification.

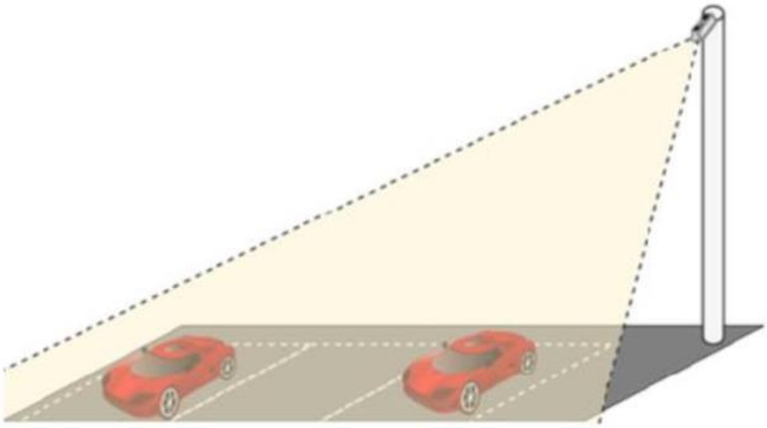

Figure 5 Parking Slot Detection with CCTV

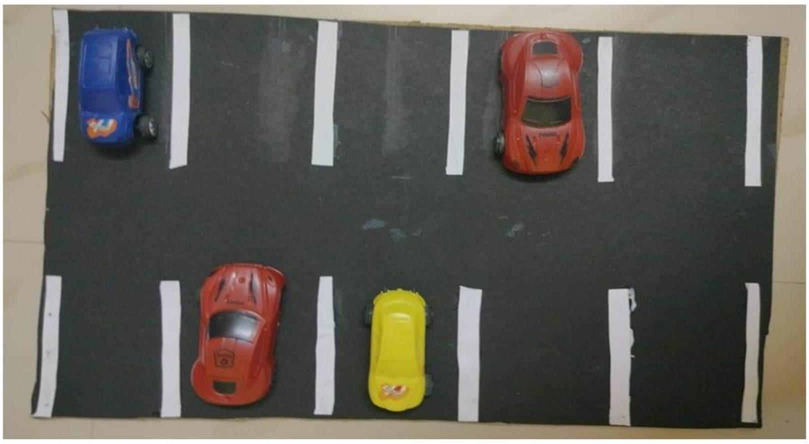

Figure 6 Demo Prototype or Testing PSD Model

As stated in the Figure 5 and 6 the model is deployed to the parking lot's CCTV camera system, where it continuously monitors parking space occupancy.

4. System design and implementation

An effective, real-time, and user-friendly parking space management solution is the goal of the APMS development and deployment. This section describes the main elements and procedures that went into creating the system, such as the overall system design, the integration of the camera module, the training and integration of the AI model, and the interface design of the mobile application.

4.1 Design of the parking management system

The intelligent, automated, and scalable approach to parking space management in urban settings is at the heart of the Parking Management System's design. The system makes use of cutting-edge technologies, such as AI for parking slot detection and vehicle identification, the IoT for real-time data collection, and a mobile application for user interaction. uses a modular design that divides software modules and hardware components (such as cameras and sensors) to allow for easy upgrades and scalability. Installs a real-time dashboard to track vehicle information and parking space availability. Uses a RESTful API to facilitate smooth communication between the software system and hardware devices. Makes use of cloud-based storage to analyze parking patterns and manage data centrally. Enables contactless and automated payment processing by integrating payment gateways such as

Stripe and UPI. Enables a responsive and intuitive user interface on all devices by utilizing Progressive Web App (PWA) technology. A notification system is included to warn drivers.

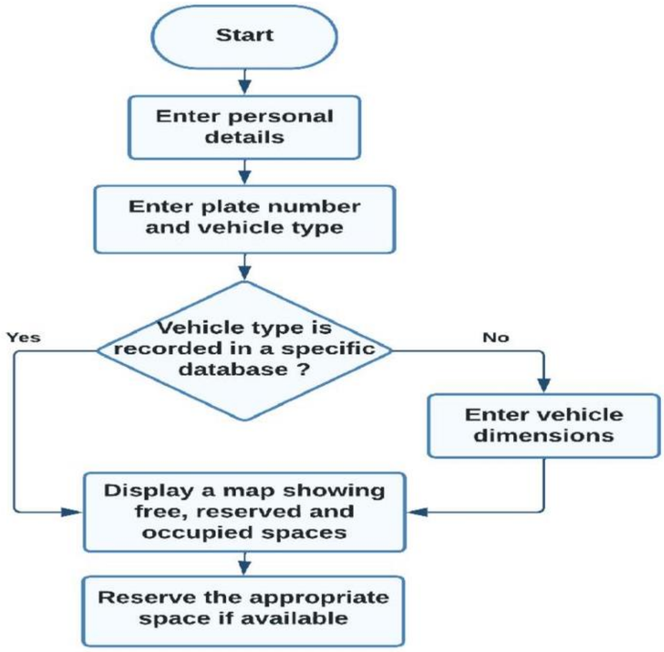

Figure 7 Functional Flow of Application

Flow of Function: 1. Vehicle Entry: As seen in Figure 7, cameras record a car's license plate as it pulls into the parking lot. The License Plate Recognition (LPR) AI model then processes the data. 2. Parking Slot Detection: CCTV cameras use a Parking Slot Detection AI model to continuously monitor parking slots and identify occupied or vacant spots. 3. User Notification: As illustrated in Figure 8, the backend server interacts with the mobile app to provide real-time information on parking space availability and to notify users when their car pulls into the lot or when a parking space opens up.

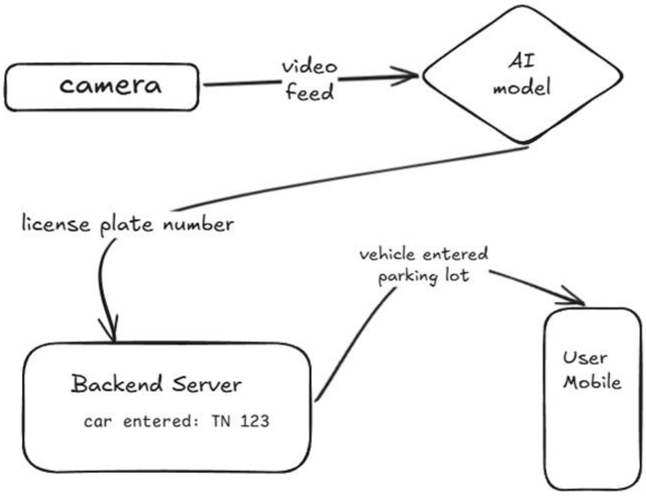

Figure 8 Vehicle Entry Flow

4.2 Design of the user interface (UI)

The Autonomous Parking Management System is accessed through the mobile application. To give users a flawless experience, the app is made to be extremely responsive and easy to use. The app shows current parking space availability information. It visually depicts the parking lot layout, indicating which spots are occupied and which are available, using the Google Maps API or comparable mapping tools. As shown in Figure 9, users can filter the available spaces according to their preferences, including location (close to the entrance), space size, or parking duration. As the car pulls into the parking lot, the app alerts users when the LPR system has successfully registered their car. This guarantees real-time user information. The app allows users to book parking spaces and pay with integrated payment gateways like Stripe or UPI. For speedy payment processing, the app allows scanning QR codes. Push alerts are sent to users for a number of occasions, such as confirmations of payments, parking availability, and successful reservations. Parking fees are determined by the system based on the amount of time spent in the lot, and after payment is made, a receipt is sent via the app.

Figure 9 Application UI

Table 1 Overview of System Components

Component	**Purpose**	**Technologies Used**
Camera Module / CCTV	Entry detection and parking monitoring	High-definition CCTV Camera
AI Model LPR	Identify and extract license plate numbers of vehicles entering the parking lot	YOLO, OpenCV, Deep Learning
AI Model PSD	Detect available and occupied parking slots in real-time	YOLO, OpenCV, Deep Learning
Backend Server	Centralized data processing	Python, Flask, SQL Database, Cloud (AWS)
Mobile App (UI)	Interface for users	React, Firebase
Payment System	Process Payments	Stripe API, UPI QR

5 Experimental setup

For the APMS to be demonstrated in practice and function, the experimental setup section is essential. The hardware setup, AI model performance assessment, and IoT network performance in terms of data handling and system communication are described in this section. In order to accomplish real-time vehicle detection, parking slot monitoring, and user interaction, every component of the system is assessed to make sure the integrated technologies operate smoothly and effectively.

Figure 10 LPR Model on Action

With an emphasis on identifying license plates from video feeds, the LPR model was deployed on a laptop utilizing a pretrained deep learning model, as seen in Figure 10. Images of cars with visible license plates were used to simulate the video feed for the experiment, and the system successfully identified and detected the plates.

Data Acquisition: The LPR 24 model was tested using a dataset of car photos. These photos were chosen in order to simulate various environmental factors, including changes in lighting, distance, and angle. Model Training: A dataset of public license plate recognition was used to train the LPR model. Convolutional Neural Networks (CNNs) were used by the model to identify license plates and extract important features from the picture.

Figure 11 Capturing of License Plate

Data processing: To improve the quality of the input images, the dataset was preprocessed prior to training. The license plate image is captured and read by the system that depicts the vehicle entry flow in Figure 11 above, allowing us to conveniently control the vehicle entering the parking space.

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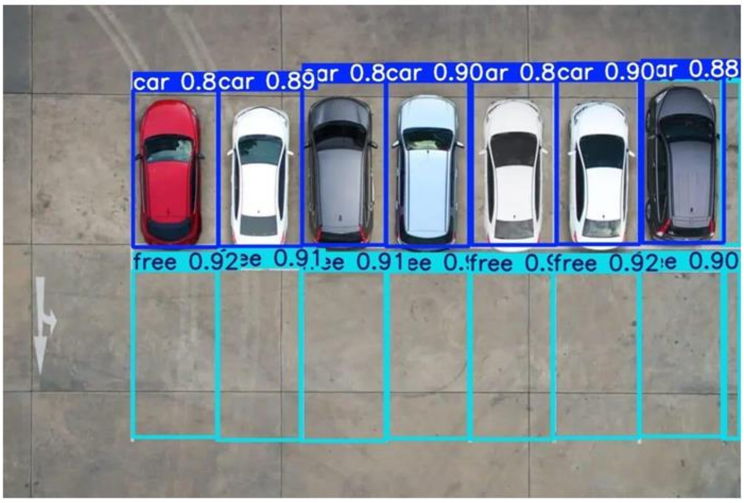

Figure 12 PSD Model on Action

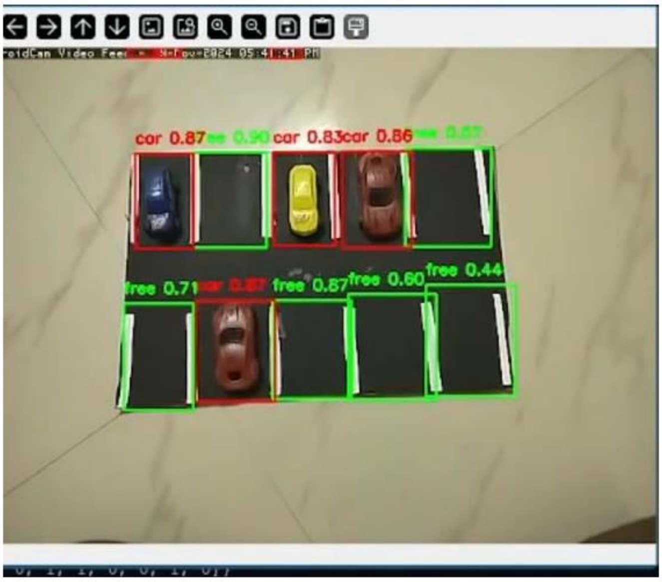

Figure 13 PSD Model Live Testing with Prototype

Deployment: To conduct tests, the trained model was set up on a laptop that was processing video feeds using Python scripts. As shown in Figures 12 and 13, the video frames were captured using OpenCV, and the model processed each frame to extract the license plate number.

5.1 AI model performance evaluation

Accuracy, Processing Time, and Recognition Rate were among the key performance metrics used to assess the LPR and PSD models. Accuracy: The proportion of correctly identified license plates among all processed vehicles. Processing Time: The typical amount of time required to handle one video frame and identify the license plate. Recognition Rate: The model's capacity to recognize license plates from different angles and in different lighting conditions. Under controlled circumstances, the model's overall recognition accuracy was 93%, with very few errors brought on by distortions like angle or low resolution. In order to manage real-time video streams, the processing time was optimized, guaranteeing prompt detection for parking lot entry systems. With an accuracy of almost 95 percent, the model's recognition rate was especially noteworthy in well-lit environments. However, under difficult conditions like low light or headlight glare, performance somewhat declined, underscoring the necessity for additional preprocessing technique optimization. With an accuracy of 92% across, the PSD model successfully identified the availability of parking spaces, demonstrating strong detection capabilities. Figure 14 and 15 shows the loss curves and the metrics that was obtained during the training of the model.

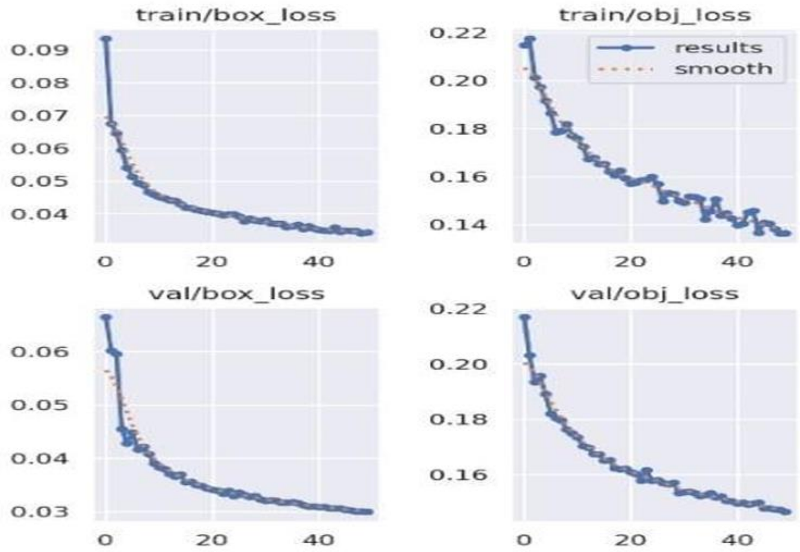

Figure 14 Loss Curves for PSD Model

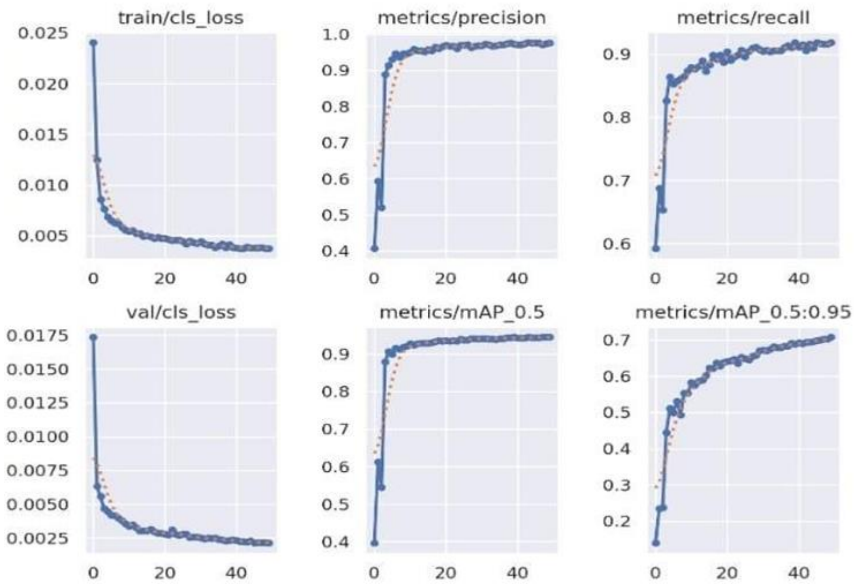

Figure 15 Training Metrics for PSD Model

YOLO with GPU support and transfer learning on a labeled dataset were used to train the parking space detection model on Google Colab. To improve robustness, hyperparameter tuning and data augmentation were used. Performance was assessed using metrics like mAP and precision. The majority of misrecognitions in the LPR model were caused by motion blur or severe distortions in video streams, according to error analysis. In a similar vein, the PSD model occasionally failed to identify parking spaces blocked by unforeseen items like carts or debris. These results point to areas where robustness could be improved by additional fine-tuning and model retraining. The system's overall performance (Figure 16) facilitates its incorporation into actual parking management systems by offering a dependable, real-time solution for parking slot detection and license plate recognition.

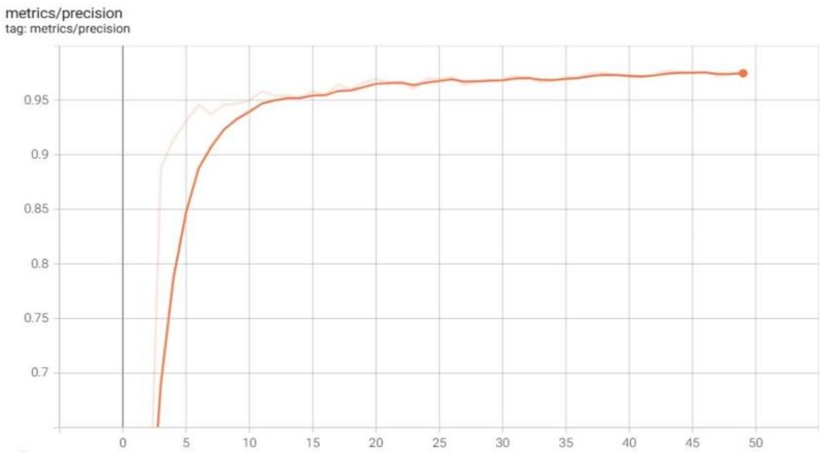

Figure 16 Precision Curve of PSD Model

5.2 IoT network performance and data handling

In order to facilitate communication between the AI model, the laptop, and the backend server for additional processing and notifications, the IoT network was configured for this experiment. The system architecture was created to mimic the model's behavior in an actual parking lot. IoT Network Configuration: To process the LPR data, the laptop was connected to an IoT-enabled server that functioned as a cloud backend. In order to transmit identified license plate numbers in real time, the LPR model interacted with the server. Data Handling: Using a simple protocol for real-time communication, the system managed data transfer from the laptop to the backend server. The backend was in charge of notifying the user and recording the vehicle's entry. Mobile Notification: The backend will alert the user through the mobile app in subsequent testing when a vehicle's entry is detected. The configuration showed how an intelligent parking system's real-time notifications could be sent via the Internet of Things network. Network Latency and Throughput: To guarantee smooth communication, the system was tested for latency and data throughput. 150 ms was the average data transfer latency between the laptop and the backend server, well within reasonable bounds for real-time applications. By simulating a busy parking lot, the network showed that it could manage several connections at once without experiencing appreciable performance degradation.

6 Results and Discussion

The outcomes of the experiment show how well the integrated system handles the main parking management issues, including tracking vehicle entries, real-time space availability, and user convenience. Both users and parking lot operators enjoy a much better parking experience thanks to the autonomous parking management system's integration of AI and IoT technologies.

6.1 Model training

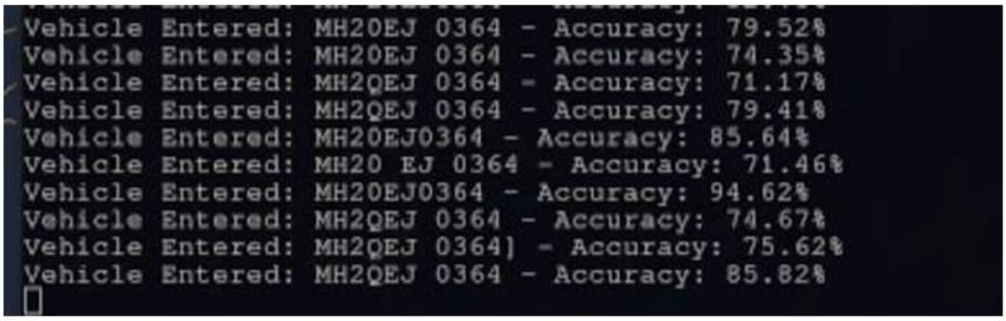

Figure 17 LPR Model Outputs

There were very few lags between the vehicle's entry and the mobile app's recognition of it. This guarantees that users can reserve open spots as soon as they arrive. Users received accurate push notifications about available spaces and reservations, which improves user experience and guarantees improved traffic flow in the parking lot. According to Figure 17, when a car enters the parking lot, its license plate is shown to record the entry and calculate how long it has been parked in a space.

Figure 18 PSD Model Outputs

The system determines the total number of parking spaces, both filled and empty, as seen in Figure 18. Each parking space's status is represented by the Data array, where 0 denotes an empty space and 1 denotes a filled one. Users can find empty spots more quickly thanks to this output's clear, user-friendly view of parking availability in real-time.

6.2 Model development and integration

To guarantee real-time data accessibility and smooth user interaction, a number of steps were taken to integrate the parking detection model with the frontend. Turning the Model into an API with FastAPI: The parking slot detection model was exposed as a RESTful API by being encapsulated within a FastAPI application. By facilitating communication between the AI model and the frontend, this API makes it possible to dynamically retrieve updates on parking slot availability. Parking Data Storage in PostgreSQL: A PostgreSQL database contains the detected parking slot data, including availability status, timestamps, and slot IDs. Users can access historical booking and availability data thanks to this, which guarantees effective data retrieval and persistent storage. Dockerizing the System: Docker was used to containerize the PostgreSQL database and FastAPI backend, guaranteeing scalability and ease of deployment. Because the database and API operate in separate containers, managing dependencies and deploying the system in various environments is made simpler. Developing API Routes for Frontend Integration: To enable the frontend to obtain real-time updates on available and occupied slots, a specific API route was developed to retrieve parking space data. Creating the Frontend with Astro and Integration: Astro was used to create the frontend, which offers a quick, lightweight interface for users to check the availability of parking spaces and make reservations. There was integration with the API.

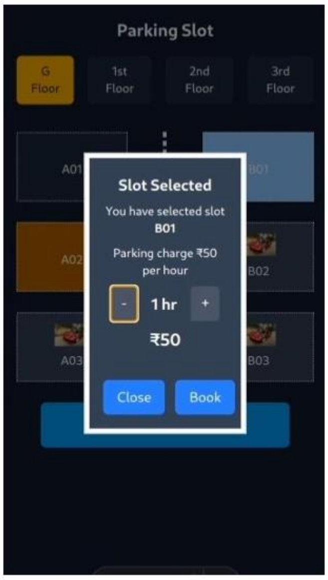

Figure 18 Booking Process Popup

The booking confirmation popup appears when a user chooses an open parking space, as seen in Figure 18. The price, booking duration, and slot number are shown in the user interface. This stage guarantees the booking process's transparency and enables users to confirm information before completing the payment process.

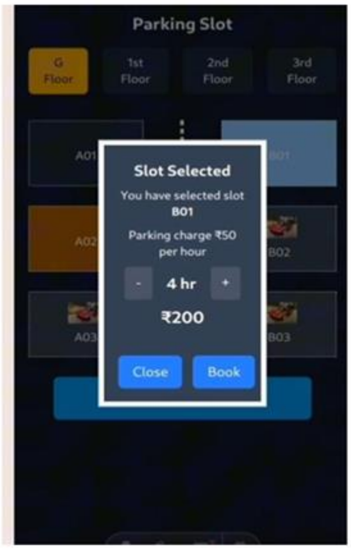

Figure 19 Booking confirmation for extended parking

The booking confirmation for a four-hour extended parking period is displayed in Figure 19 above. The system gives users the ability to dynamically change the length of their reservation, guaranteeing flexibility according to their parking requirements. Last-minute annoyances like unanticipated fines or forced relocations because of exceeding parking limits are avoided by the system, which enables users to extend their parking duration directly through the app. A hassle-free user experience is also offered by the system's integration of automated payment adjustments, which means that any extension in the booking period is handled immediately through the Razorpay payment gateway. Because real-time updates guarantee that slots are effectively managed, the ability to easily change booking durations also enhances overall parking space utilization. The Razorpay payment gateway integration, which offers a smooth transaction process, is highlighted in Figure 20. A seamless and dependable experience is ensured by the secure payment methods available to users.

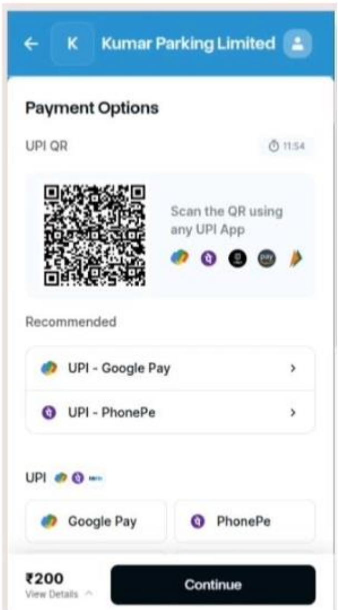

Figure 20 Razorpay payment gateway integration

A seamless and hassle-free experience is ensured by the confirmation mechanism, which ensures that users are informed promptly about their updated booking status. This is especially critical for parking management systems, where real-time updates are essential for avoiding user confusion and duplicate reservations. The payment confirmation screen that shows up after the transaction is successfully completed is shown in Figure 21 below. The booking process is made less uncertain for users by providing them with an instant confirmation. This screen acts as a formal confirmation that the user's payment was received and that their parking space was reserved.

Figure 21 Payment confirmation screen

As seen in Figure 22, the system takes the user to the payment success page following a successful payment and confirmation. A successful payment message is shown on this page, signifying that the user's transaction was accepted and that their parking space was safely reserved.

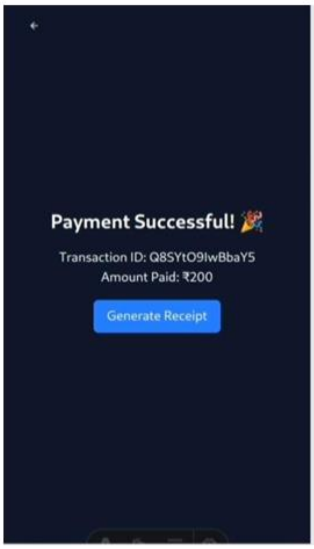

Figure 22 Payment Successful Message

A digital receipt with important information like the booking ID, payment amount, parking slot number, and booking duration is automatically generated by the system. You can use this digital receipt for record-keeping and verification. Additionally, users have the option to download a PDF of their parking receipt. This guarantees that customers have a copy of their reservation information, which they can show to parking lot employees if necessary. An example of a generated receipt is displayed in Figure 23.

Figure 23 Receipt Generation

Conclusion

Efficiency, accuracy, and environmental sustainability have all shown notable gains since the installation of an AI-driven parking management system. The system effectively detects parking slot occupancy and automates license plate recognition by utilizing deep learning and computer vision techniques, which lessens the workload for human operators and improves user convenience. The project guarantees smooth scalability and accessibility through cloud deployment and real-time data processing. Future developments in intelligent transportation systems are made possible by the incorporation of AI-driven decision-making into smart city infrastructure. Fuel consumption and carbon emissions are directly impacted by the shorter search times for parking spots, so the solution is not only an operational improvement but also an environmentally beneficial endeavor. The project's potential for widespread implementation is demonstrated by its ability to interface with urban mobility solutions, which will aid cities in maximizing space utilization and easing traffic. This study advances the larger objective of smart city development, which aims to improve urban infrastructure through the cooperation of automation, AI, and cloud computing. Future improvements, like incorporating real-time traffic data, predictive analytics, and mobile applications for a smooth user experience, will be made possible by the project's success. All things considered, this AI-powered self-parking management system is a positive development.

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