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AI-Driven Parking Management: ANPR-Based Entry & Biometric Gate Control

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There is now a greater need for effective and safe parking solutions due to the growth in urbanization. To provide an anodyne parking experience, this article introduces an AI-driven parking management system that combines biometric authentication for gate control with Automatic Number Plate Recognition (ANPR) for vehicle classification. This paper will present an IoT-based automatic number plate recognition (ANPR) and biometric gate control system designed to optimize parking management through automated vehicle access. We suggested a biometric-integrated Internet of Things-based parking access management system with fingerprint recognition for user authentication. The system uses a Raspberry Pi 4 as its central controller and uses automatic number plate recognition (ANPR) to classify vehicles. Our suggested framework will utilize the camera to capture images of vehicles, then extract the license plate number and compare it to a database of permitted vehicles using ANPR software for vehicle classification and allocation. The system uses AI and IoT-based technologies to enhance security, automate vehicle entrances, and track real-time parking occupancy. Only registered users or authorized personnel are permitted to enter the restricted parking area. The proposed system is designed to operate in real-time, minimizing unauthorized access, reducing congestion, and enhancing overall parking efficiency. As a result of integrating with IoT systems, the solution will improve security and operational efficiency by enabling real-time monitoring, dynamic updates of parking availability, and logging of entry and exit events.

Keywords: ANPR (Automatic Number Plate Recognition), Biometric Gate Control, IoT, Parking-Management-System, Vehicle classification.

Introduction:

Smart parking management poses a major challenge in densely populated areas. The rising number of vehicles and the scarcity of available parking spaces call for innovative and efficient solutions. The Internet of Things (IoT) provides a network of nodes that may communicate with each other, including people, computers, and objects. By integrating devices capable of sensing, processing, and transmitting information to both peers and central systems, IoT fosters network expansion and drives technological innovation [1]. IoT improves device intelligence by monitoring and evaluating network nodes that are connected. It authorizes sensor networks [2], radio frequency identification (RFID) [3], and terminal computing systems, the three fundamental elements of the Internet of Things that are vital to its operation. Many strategies have been implemented and examined for real-time monitoring and recognition [4]. A geomagnetic sensor-based intelligent parking management system was created to solve problems with predictable parking facilities. When location data is integrated with LIDAR technology [5], vehicles parked in a predicament can be recognized. Through visualization, the system guarantees accurate and steadfast vehicle location. In our proposed techniques, the requirements for parking spaces are shown on liquid crystal screens controlled by a central server. The positional precision of the geomagnetic sensor [6] is within 0.4 meters, and the packet loss ratio of the remote entity is trivial within 150 meters [7]. A smartphone application allows users can locate open parking spots, saving time, money, and gas when looking for locations. Additionally, parking station managers can reserve spaces directly through the app, which helps to enhance efficiency and validate data [8]. The recommendation proposed in this article is to create a terminal and a smartphone application that can easily and rapidly notify a driver where their car is parked. The place to park can be substantially decreased using intelligent parking systems that utilize location monitoring, contributing to declining air pollution generated by cars inside buildings. To assist drivers in returning to their vehicles, most of the current advanced parking systems use an instrument installed in every parking spot to identify if a vehicle exists. This system additionally displays letters and numbers in a massive type adjacent to each lot. However, most of the inside parking places have cameras, that imaging device can be situated in a method to give an image of the parked lot that emphasizes that vehicle's license plate, then employ image processing techniques to detect the license plate number and maintain it in a local database that can be examined from any place in the parking lots network [9]. It can be useful in such a situation wherein a safety officer is not present, because automatic parking systems eradicate the requirement of manual efforts. An algorithm, ANPR, will be applied to CCTV footage [10] to recognize a vehicle's license plate, determine the number from the plate, and then generate an entry for the vehicle in the database [11]. Author[12] proposed a system that introduces biometric fingerprint recognition as a robust access mechanism within a smart parking environment, integrated with ANPR (Automatic Number Plate Recognition) for vehicle classification. Biometric technology can play a significant role in reducing criminal activity due to its robust security features, accurate identification capabilities, and reliable traceability [13]. IoT technology can enhance security, decrease waiting time, and improve traffic control [14].

Problem Statement:

An IoT-based system for vehicle recognition and monitoring is used in different hardware and software components that are integrated into each other. Figure 1 illustrates the hardware and software components. As motor vehicles, coaches, and motorbikes approach a regulated location, the camera collects photos of them. Computational devices, like a Raspberry Pi 4, examine the images and execute responsibilities like license plate identification. After interpreting, the data is maintained in a database, where it can initiate operations such as logging entries or permitting entry. The purpose of utilizing biometrics for gate control in an Internet of Things-based parking management system is to enhance security and expand access. By limiting access to the parking facility to approver users, this integration lowers the rate of unauthorized entry and boosts overall operational effectiveness. It detects automobiles that do not follow signals using a camera and a Raspberry Pi 4. It then delivers an SMS to the authorities, saving the vehicle's registration information in a database. In addition, the software makes sure that emergency vehicles receive precedence by turning on the green signals needed. IoT is extremely beneficial for smart city applications since it integrates, i.e., sensor networks, RFID, and interface computing, allowing device awareness via continuous tracking and data interpretation. It encompasses geomagnetic sensors, LIDAR technology, and position data to monitor and coordinate parking. In addition to creating real-time vehicle identity, this approach makes it convenient for users to retrieve parking areas through SMS, reducing search time and the harmful impact of vehicle emissions.

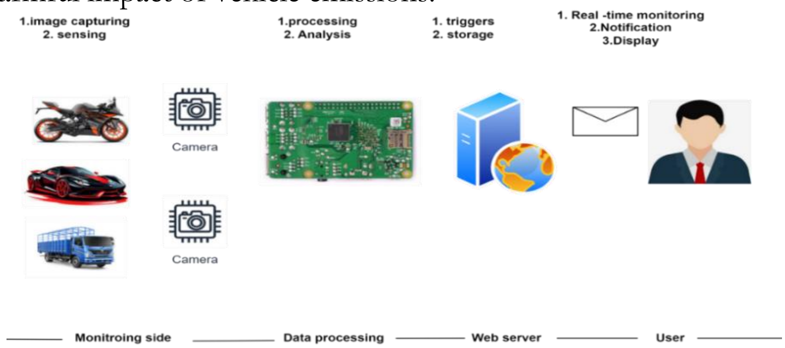


Figure 1. Hardware and Software integrated components used in the Parking Management System

Objective of the Study:

The key objective of this study is to design and simulate an AI-powered smart parking system that integrates biometric gate control and automatic number plate recognition (ANPR) within an IoT infrastructure. For instance;

- Enhancing parking security by integrating fingerprint-based biometric verification.
- Reducing congestion and unauthorized access by enabling real-time monitoring and control.
- Automating vehicle entry, classification, and parking space allocation using ANPR and IoT.
- Demonstrating the system's effectiveness through MATLAB-based simulation, focusing on speed, accuracy, and predictive maintenance.

This study aims to fill current gaps in parking systems by offering a secure, integrated, and cost-effective solution suitable for urban environments. It is appropriate for urban environments that involve shopping centers, workplaces, and cooperative communities.

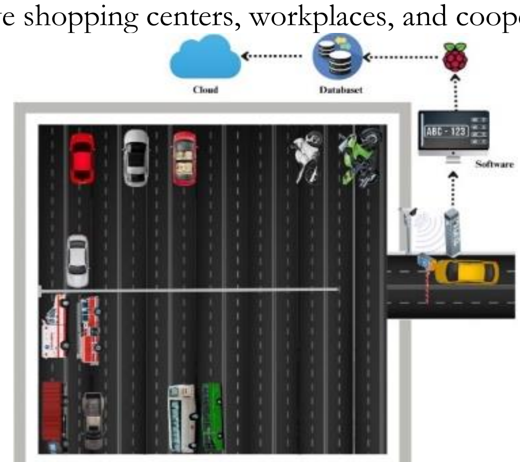


Figure 2. Integrating IoT, Biometrics, and ANPR for Smart Parking

Literature Review:

Many studies focus on the planning and architecture of IoT networks. The literature on these particular topics was briefly reviewed in this section.Author [15] investigated the use of IoT-based technologies in smart cities to address challenges related to parking space management. Their suggested innovative parking system uses an Internet of Things infrastructure to gather and send real-time data to cloud computing services, which notify vehicles about adjacent parking spaces. A smartphone app for this system assists users in finding and parking in available spots. An innovative city application with an automated parking system and a unique iOS app was presented by author[16]. With the help of this software, drivers can locate and book parking spots in neighborhoods, saving time when looking for spots. The study emphasizes the advantages of reservation strategies, which reduce fuel use and carbon dioxide emissions, save needless travel through crowded regions, and deal with several urban transportation-related concerns. Author[2] suggested building an intelligent parking platform using the Internet of Things and the Arduino UNO model to enable free car parking reservations for college campus activities. The method maximizes first-come, first-served scheduling by using passive infrared and ultrasonic sensors to identify open parking spots. This framework shows how parking allocation efficiency can be improved through the use of IoT. A smartphone application lets users register and pay for parking spaces while giving them access to real-time information about available spaces and directions to the closest parking lots [8]. A Raspberry Pi [17] system controls parking lots, collecting data from cameras and sensors to allocate spaces efficiently. The KNN algorithm's integration with OpenCV [18] improves the system's ability to detect license plates quickly and accurately. Raspberry Pi [19], IR sensors [20], USB cameras [21], and ultrasonic sensors are some hardware components. The database is Google Firebase, and Python is used for deep learning operations. A new IoT-driven Smart Parking Management System (SPMS) named IOT-SPMS Lora-WAN was presented by author[22]. It uses long-range comprehensive area network technology to overcome earlier systems' drawbacks, such as limited communication range, power consumption, and installation costs. The intelligent sensing nodes in the system are Arduino [23] UNO microcontrollers, waterproof ultrasonic sensors, and triaxle magnetic sensors. These sensors count the number of parked cars and provide data to the server through the LoRa-WAN gateway [24]. Automatic parking systems use Automatic Number Plate Recognition (ANPR) to verify vehicle authorization. The system checks whether the vehicle is registered or known to the property; if it is not recognized, access is denied. The system detects the vehicle number plate using the Yolov4 algorithm and uses optical character recognition (OCR) to extract characters and checks in the database [11]. Users can manage a list of authorized vehicles to grant access. The proposed solution aims to enhance security, minimize reliance on third parties, and improve the overall efficiency and response time of the system. The authorsuggested a scheme that depended on three image processing stages to accomplish license plate identification with high accuracy: pre-processing, character recognition. The smooth edge detection technique with numerous thresholds, outline detection, and masking procedures is used to locate the vehicle's edges and license plate [9].

Table 1. Previous Literature Work and Their Technique

Authors	Objectives	Techniques	Limitations
M. Abdellatif et.al [8]	It provides a solution to poor parking management and issues of stolen vehicles.	Using smart edge detection, shape detection, OCR, and a Database.	The current model requires further large-scale deployment testing.
A. Jabbar et al. [17]	It provides a smart parking system for the campus.	Using a Pi camera module, ultrasonic	Security, classification requirement.

		sensors, and a GPS sensor	
L.HEMANTHI et al. [25]	It provides real-time information on parking availability using the mobile application.	IR sensors, mobile applications, and database and cloud storage for parking patterns.	Security, classification requirement.
Parab et al. [10]	Reduce human interaction and errors. Provide quick and easy vehicle number plate detection.	OCR technology, YOLOV4 algorithm, CCTV camera, and GUI.	Manual systems lead to unknown errors and delays.
Veeramanickam et al. [2]	Analyze various scenarios for parking allotments during parking time	Arduino UNO, Passive Infrared and ultrasonic sensor, FCFS Algorithm.	Security requirement
Mihir Jadhav et al. [13]	Manage traffic destiny and signal timing effectively.	IR sensor, SMS alerts for traffic violations, Raspberry Pi.	Parking allotment based on vehicle classification

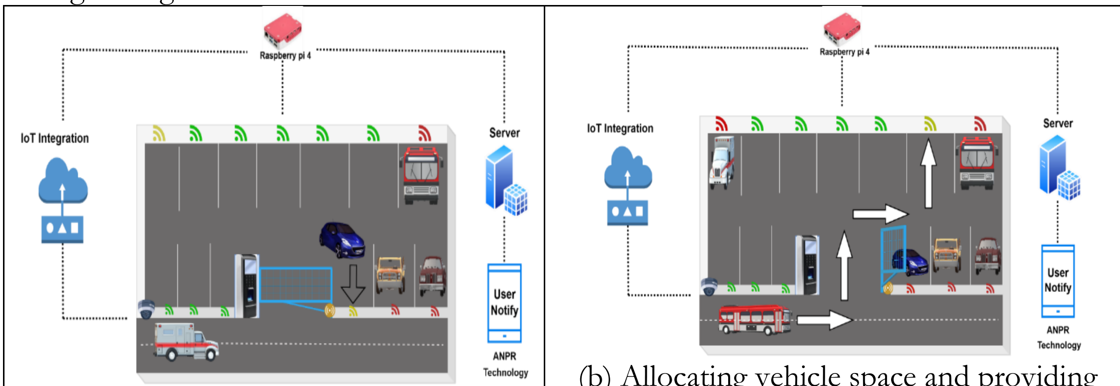
While previous works have contributed valuable insights into smart parking, most suffer from limited integration, a lack of real-time monitoring, or the absence of biometric access control. Existing smart parking systems often focus on either vehicle recognition or access control, but not both in an integrated, real-time system. Additionally, many systems lack robust security features, real-time monitoring, and predictive maintenance. This study addresses these limitations by combining ANPR with fingerprint biometrics in a unified IoT framework, offering a secure, automated, and cost-efficient solution that minimizes manual intervention and supports real-time analytics.

Methodology:

The current research proposes an IoT-driven intelligent parking management system, a biometric gate control, and an ANPR system for real-time automation. The system incorporates cameras to take images of vehicles, and ANPR technology identifies and correlates the photos to a database of recognized vehicles to regulate barrier procedures. The Raspberry Pi 4 acts as the system's central controller. The solution assures superior safety and efficient operation through integration using an IOT system to provide continuous monitoring, entry and departure exploitation, and periodic notifications of where to park. It differentiates automobiles into classes, including private vehicles, trucks, motorbikes, electric vehicles, emergency vehicles, and public transport. Space is subsequently divided, corresponding to specifications such as EV charging or emergency vehicle priority access. This affordable, adjustable, and sustainable system enables a secure, productive, and intelligent method of contemporary parking management in various circumstances, such as malls, workplaces, and apartment complexes.

Figure 3 demonstrates an IoT-based Automatic Number Plate Recognition (ANPR) and Parking Management System that automates vehicle entry, parking allocation, and monitoring. When a vehicle arrives, a camera captures the vehicle, and the image is processed by a Raspberry Pi 4 using ANPR software to extract the number, which is then checked against a database.

Once verification is successful, the gate opens, and the system classifies the vehicle (e.g., bike, car, truck) to assign a suitable parking space accordingly. Real-time monitoring tracks occupancy and system performance, while predictive maintenance identifies potential issues before they occur. If certain conditions are met, such as parking time limits or maintenance needs, SMS notifications are sent to the relevant parties, ensuring efficient and seamless parking management.



(a) Capturing Vehicle Information

(b) Allocating vehicle space and providing direction

Figure 3: (a), (b) System Architecture, IoT-based ANPR and Parking Management System

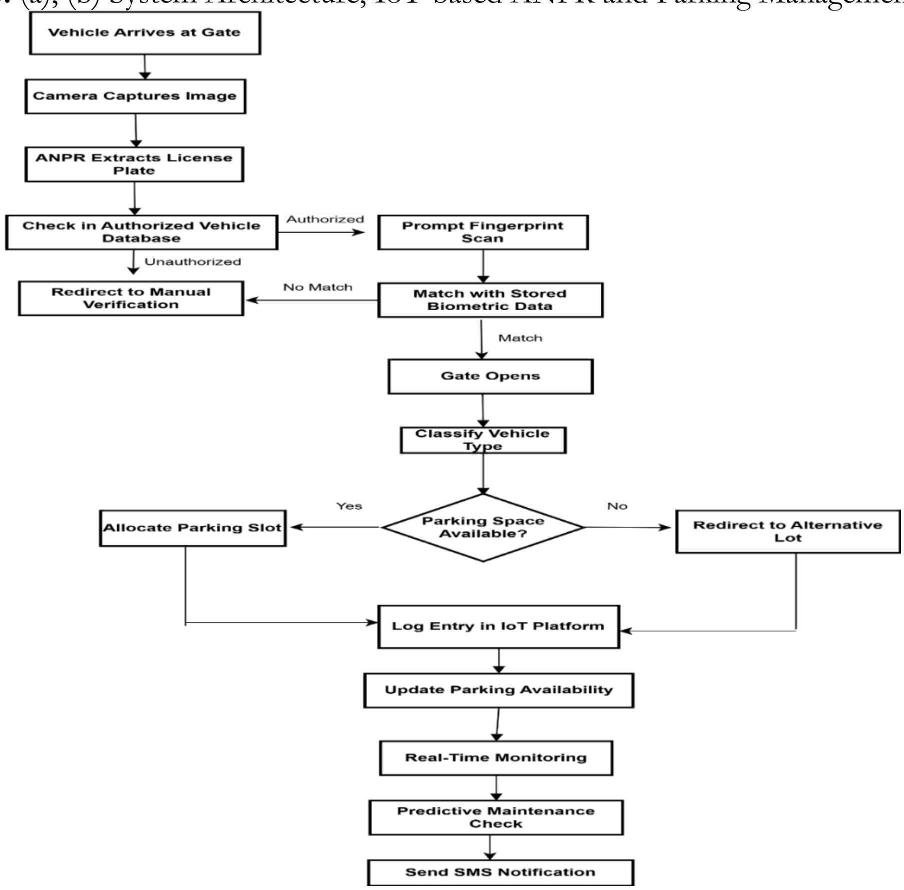


Figure 4. Flow Diagram of Proposed Methodology

Our proposed design introduces a bidirectional authentication mechanism to enhance vehicle security and ensure the efficient utilization of parking spaces. The user initially applies a fingertip touch to the biometric gate control application. A pattern stored in the database is compared to the fingerprint by the system. The system goes on to vehicle classification if authentication is successful. Once the vehicle image has been captured, the ANPR module classifies the type of vehicle. An IOT-based ANPR and smart parking management system that optimizes vehicle entry, categorization, and parking reservation is displayed in Figure 4. The Raspberry Pi 4 employs ANPR software to examine and verify permissions for the vehicles that the camera records. If the vehicle is successfully verified, the gate opens and the entry is recorded on the IoT platform. If verification fails, the vehicle undergoes manual inspection. The system classifies the types of vehicles (car, bike, bus, etc.) and ensures that traditional parking is feasible. Vehicles are allocated to available parking spots; if no spot is available, they are redirected to an alternative parking area. While automated maintenance finds flaws and alerts the appropriate staff via text message, real-time monitoring ensures the most accurate access to parking, ensuring seamless, reliable parking. This system then dynamically assigns parking spaces depending on the categorizations. The system determines whether the user and vehicle are permitted before activating the gate control mechanism: the IoT platform logs and updates real-time data for analysis and monitoring.

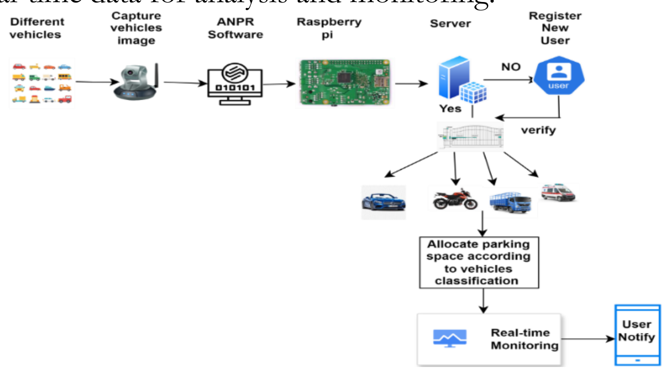


Figure 5. System working flow for IoT-based ANPR and Parking Management System

Our proposed approach utilizes fingerprint verification to control gate access for both entry and exit. Upon scanning, the system analyzes the fingerprint, generates a unique template based on the processed data, and stores it for future authentication. When the user inserts their finger, the system uses an optical sensor to produce a template of the finger, which it then compares to templates from the finger library. Using specialized scanners, an image of the fingerprint is initially created to extract certain features such as ridge ends and bifurcations.

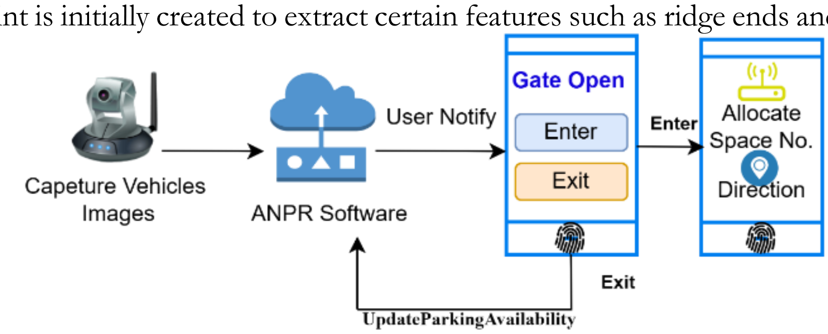


Figure 6. Biometric Gate Control Process for IoT-based ANPR and Parking Management System

The fingerprint biometric is then digitally represented using these features, producing a mathematical representation of its distinct characteristics. Fingerprints are always available to the individual, eliminating the need to carry identification cards or remember passwords, thereby enhancing both convenience and security. Fingerprints are difficult to replicate and remain largely unchanged over time. Their non-transferable nature ensures more accurate tracking and enhanced security. Give a step-by-step pseudocode of the Biometric Gate Control Parking System's operation in Algorithm 1.

Once the system captures vehicle information through the camera, the image is sent to the ANPR software for processing. The ANPR system then extracts the license plate details from the captured image. The authorization checks the extracted license plate and then matches the list of authorized vehicles. If information is authorized, then proceed to the vehicle classification. If not authorized, then redirect the user to manual verification. Afterward, let the permitted vehicle through the gate, record the vehicle's entry into the IoT platform, and record the relevant information, like the time of entry, etc. After approval, the user opens the gate using the biometric technique. Consequently, biometric verification provides protection and high security.

Algorithm 1: Biometric Gate Control:

1. Set up the Biometric Application
2. Set up an IoT platform (such as Firebase or MQTT)
3. Set up the Parking database with the available parking spaces
4. Start the Gate Control System
5. Biometric Enrollment (New Users Only)
6. Request biometric authentication from the user while the system executes.
7. Capture real-time biometric information
8. Examine stored patterns against real-time data
9. Should a match be found, then Verified = "ACTIVE"
10. Matched_Template_User_ID = User_ID
11. ELSE, "Authentication Failed" is displayed
12. If the Gate is open, then
13. Use sensors to monitor vehicle entry
14. After entering the vehicle entrance, close the gate
15. Exit of Users
16. Prompt the user to re-authenticate for exit
17. Release the allocated parking slot in the database

The system classifies vehicles based on their type, including categories such as cars, trucks, buses, emergency vehicles, electric vehicles, motorcycles, and other automobiles. After determining whether conventional parking spaces are available, our suggested approach assigns the vehicle to the appropriate space. If no parking space is available in the designated area, the system automatically assigns an alternative parking location. Subsequently, the most recent parking availability information based on the space should be updated on the IoT platform. If the designated parking area has no available spaces, the system automatically redirects the vehicle to an alternative parking location. Algorithm 2 represents the pseudocode of the ANPR software working and parking allocation. Different function was called in a sequence way i.e., OpenGate(), Realtime Monitoring (), and Predictive Maintenance ().

Algorithm 2: ANPR and Parking Allocation

```
Capture an image from the camera
license_plate = ANPR_Software.extract license plate(image)
IF license_plate IN authorized_list
THEN
OpenGate()
LogEntryToIoTPlatform(license_plate, entry_time)
vehicle_type = ClassifyVehicleType(license_plate)
IF StandardSpaceAvailable(vehicle_type)
THEN
AllocateStandardSpace(vehicle_type)
ELSE
AllocateAlternativeSpace(vehicle_type)
END IF
UpdateParkingAvailability(vehicle_type)
RealTimeMonitoring()
PredictiveMaintenance()
SendSMSNotification(license_plate, parking_status)
ELSE
RedirectToManualVerification()
END IF
```

This real-time data capturing and decision-making procedure facilitates long-term predictive maintenance as well as updates on available slots. High dependability is ensured by proactively monitoring slot utilization and sensor health, which enables administrators to see possible issues before they interfere with parking operation. This approach offers intelligent, automated parking management and decreases interruptions, in addition to increasing efficiency. Algorithm 3 represents all the functions used in prediction maintenance. All necessary modules, such as sensors, data collection devices, and predictive maintenance models, are initialized at the start of the suggested algorithm. A constant, real-time monitoring loop surrounds the system's core. The system iterates through every parking space in the lot as long as it is operational. To identify when maintenance is required, particular threshold values are established for every crucial system component, including sensors, IoT gateways, and parking spaces, after they have been initialized. The method leverages integrated sensors to gather many data points for each slot. These include the battery level (to guarantee sensor persistence), signal strength (to evaluate communication reliability), error logs (to identify any operational faults), and occupancy status (whether a vehicle is present). Based on the occupancy state, the system dynamically updates the availability of each slot. If a space is designated as "occupied," it is reported as "unavailable" in the database; otherwise, it is recorded as "available."

Algorithm 3: Predictive Maintenance:

1. Initialize sensors, data collection modules, and predictive models
2. Set maintenance thresholds for each critical component, i.e., sensors, gateways, and parking slots.
3. Real-Time Monitoring Loop()
4. WHILE the system is running DO
5. FOR each parking slot IN the parking lot DO
6. Collect Sensor Data
7. occupancy_status = parking_slot.sensor.readOccupancy()
8. signal_strength = parking_slot.sensor.readSignalStrength()
9. battery_level = parking_slot.sensor.readBatteryLevel()
10. error_logs = parking_slot.sensor.readErrorLogs()
11. Update-Parking-Availability
12. IF occupancy_status == "occupied" THEN
13. UpdateParkingAvailability(parking_slot, "unavailable")
14. ELSE
15. UpdateParkingAvailability(parking_slot, "available")

Result:

The system continuously assessed parking conditions in real-time to monitor usage and forecast maintenance requirements. Predictive management algorithms are also used to handle parking management issues. Following the completion of the procedure, the parking management received an SMS containing the vehicle's current status. This method enabled the system to automatically control gate access, manage parking availability, and support real-time monitoring, thereby facilitating efficient parking management. The system's operations, including vehicle recognition, fingerprint verification, and dynamic slot allocation, were successfully simulated and validated using MATLAB. Due to financial limitations in developing a fully functional hardware-based implementation, a simulation approach was adopted. In future work, additional biometric modalities such as facial recognition will be incorporated, and AI-driven analytics will be integrated to support predictive and adaptive parking management.

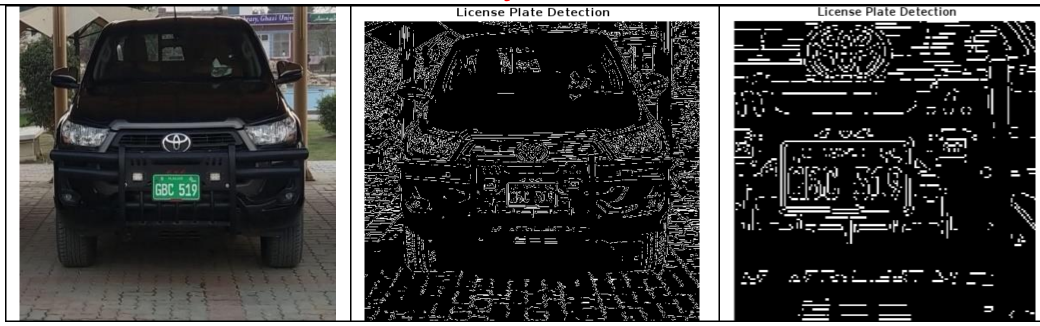


Figure 7. ANPR software extracts the license plate information

Smart Parking System simulates an IoT-driven smart parking system with vehicle recognition, parking space allocation, and biometric gate access control. Figure 7 illustrates the process by which the system captured vehicle information using the camera. To capture the vehicle's image, the information goes to ANPR processing, i.e., the captured image is sent to the ANPR software, and extracts the license plate information. The authorization checks the extracted license plate and then matches the list of authorized vehicles.

Figure 8 represents that, if access is granted, the parking slot is occupied and the vehicle parks successfully. The allocated slot remains unoccupied if access is denied, and the system releases it for other vehicles.

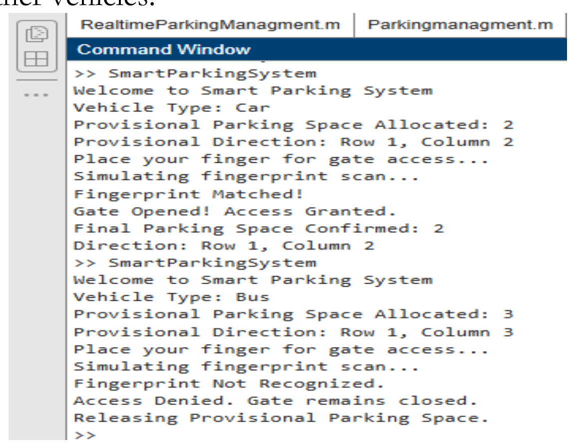


Figure 8. Vehicle Recognition, Space Allocation, and Biometric Gate Control Process

For an effective parking management system, real-time monitoring is supported by predictive maintenance for Real-Time Parking Management, depicted in Fig. 8. We successfully developed a MATLAB prototype integrating vehicle recognition, parking space allocation, and fingerprint-based gate access, represented in Figures 7 and 8.

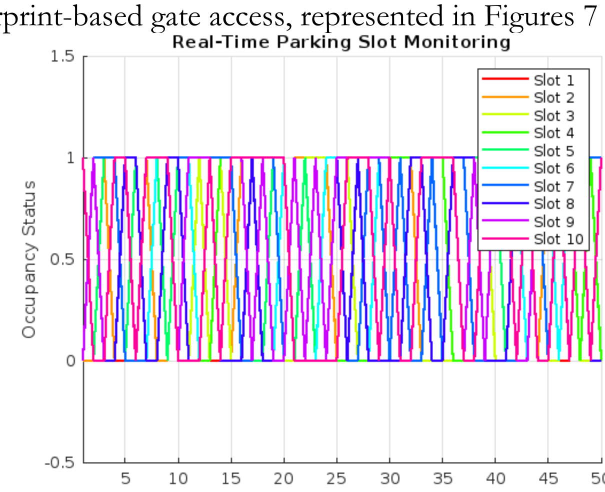


Figure 9. Predictive Maintenance System for Real-Time Parking Management

The simulation effectively demonstrated the feasibility of our approach, ensuring proper parking management and secure gate control. This cost-effective execution validates the practicality of our algorithm in real-world scenarios.

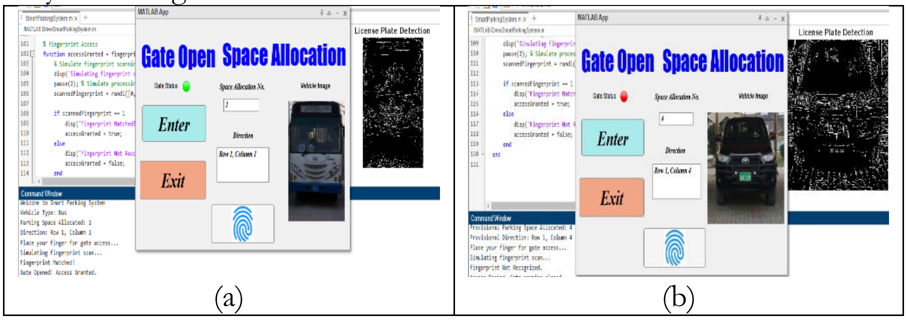


Figure 10. (a), (b) Biometric Gate Control Parking System & Space Allocation App

Figure 11 shows maintenance thresholds for each critical component, i.e., sensors, gateways, and parking slots. It represents the parking slot occupancy status, signal strength, battery level, error logs, and updates parking availability. Our proposed system predicted the maintenance system based on real-time parking slot monitoring data.

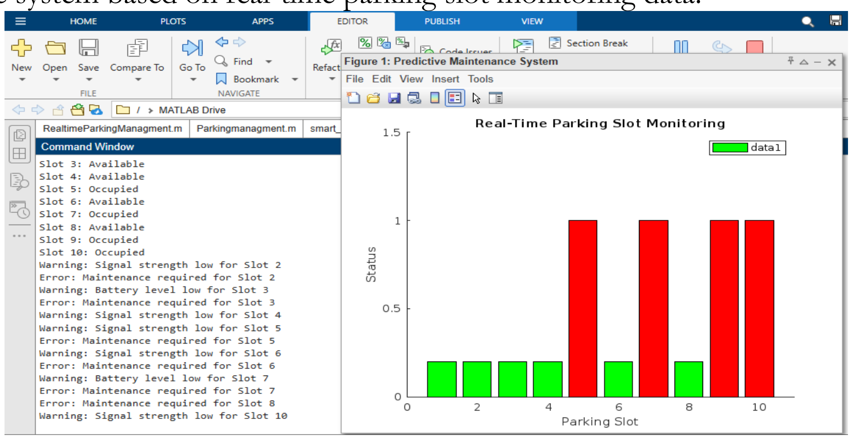


Figure 11. Real-Time Parking Slot Monitoring and Predictive Maintenance System

Figure 12 illustrates that MATLAB simulation was used to assess the smart parking system across five experimental runs. A car image was manually chosen for recognition in each trial, and then a simulated fingerprint authentication was performed. The findings show that the system had 100% vehicle recognition accuracy for all vehicle kinds, including the "Car" and "Bus" classifications. Every time fingerprint verification was performed, both authorized and unauthorized users' fingerprints matched 100% of the time. It is noteworthy that all permitted entries were accepted without error by the system, and that unauthorized access was correctly rejected in Trial 1. The system's ability to distinguish between legitimate and fraudulent users was demonstrated by the mistake rate, which was reported at 0%. The average reaction time for all trials was roughly 7.27 seconds, demonstrating the system's ability to detect vehicles, verify biometric information, and assign parking spaces within reasonable real-time limitations. These findings together validate the suggested system's accuracy, responsiveness, and dependability in simulated real-time scenarios.

Figure 13 displays the system's response time for each of the five separate trials, which included parking space assignment, fingerprint verification, and vehicle detection. The system's overall time to process input and grant access is reflected in the response time. Trial 2 had the longest reaction time (9.02 seconds), as the graph illustrates. This was either caused by a delay in image input or longer processing time during biometric verification. Trials 3 and 5, on the other hand, showed the quickest response times, at roughly 6.27 and 6.26 seconds, respectively, suggesting that the system operated more smoothly and effectively in such situations. The average response time was 7.27 seconds, with overall response times ranging from 6.26 to 9.02 seconds. The system's responsiveness and ability to manage several authentication procedures promptly are confirmed by this performance, which is well within reasonable real-time operating bounds for smart parking applications.

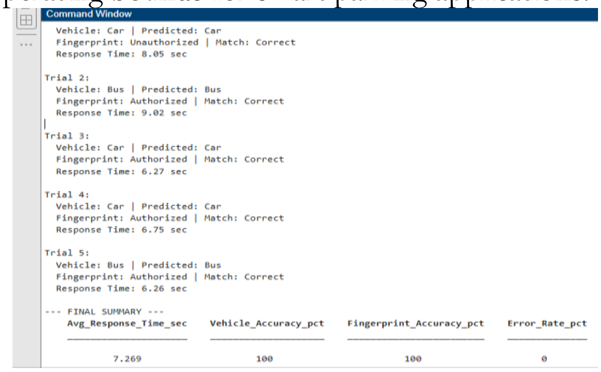


Figure 12. Real-Time Parking Slot Monitoring and Predictive Maintenance System

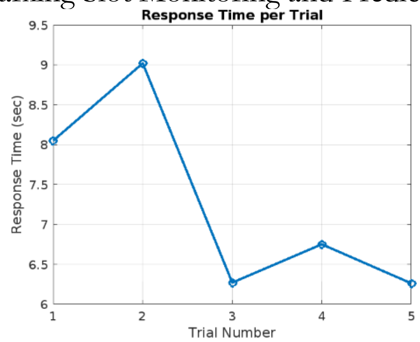


Figure 13. Real-Time Parking Slot Monitoring and Predictive Maintenance System

The "System Evaluation Metrics" Figure 14 bar chart illustrates a system's performance according to three important metrics: error rate, fingerprint accuracy, and vehicle accuracy. The system's exceptional dependability in correctly identifying vehicles and fingerprints is demonstrated by the 100% flawless scores obtained by both Vehicle Accuracy and Fingerprint Accuracy. In the meantime, there are no notable system errors or misclassifications, as seen by the Error Rate, which is practically 0%. Together, these findings imply that the system operates with remarkable accuracy and few mistakes.

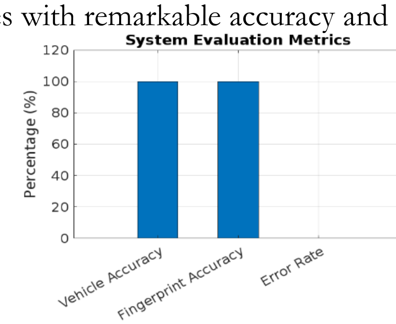


Figure 14. Real-Time Parking Slot Monitoring and Predictive Maintenance System

Discussion:

For safe, automated, and real-time car entry and parking management, the suggested Smart Parking System combines biometric fingerprint authentication with Automatic Number Plate Recognition (ANPR). All of the evaluation's major parameters demonstrate excellent performance, including 100% accuracy in vehicle recognition, 100% accuracy in fingerprint matches, a 0% mistake rate, and an average response time of 7.27 seconds across five trials. These results confirm the system's effectiveness and resilience, particularly in terms of security, responsiveness, and real-time functionality. When compared with existing studies, our system demonstrates superior or comparable results.

Table 2. Comparative Analysis with Existing Studies

Study / System	Techniques Used	Vehicle Recognition Accuracy	Fingerprint / Biometric Used	Error Rate (%)	Avg. Response Time (sec)	Observations
Proposed System (This Study)	ANPR + Fingerprint + IoT (MATLAB Simulation)	**100%**	**Yes** (Fingerprint)	**0**	**7.27**	Secure, Multi-Factor, Real-Time
Veeramanickam et al. (2020)	IoT + Camera Image Detection	~90–93%	No	~6–8	~9.5	No biometric security
Sharma et al. (2021)	ANPR + IoT	92.8%	No	~7	~10.2	High ANPR error in low light
Parab et al. (2022)	ANPR + RFID	~95%	No (RFID-based)	4–6	~10	RFID risk of duplication
Abdellatif et al. (2023)	IoT + Arabic ANPR model	95–97%	No	~3	~7.5	Language-specific (Arabic plates)

However, the system proposed a hybrid multi-factor authentication technique that makes it more resistant to undesired access by combining visual-based ANPR with biometric validation. The immediate verification takes less than 8 seconds, and 0% mistake rate makes real-time deployment possible even in moderately busy urban situations. Furthermore, fingerprint authentication eradicates the need for physical tokens like RFID cards, which are vulnerable to theft or misuse, and fosters confidence. The simulation showed consistent performance across multiple tries, proving the technology's dependability. Despite strong results, the current evaluation is based on MATLAB simulation and controlled test images.

Conclusion:

Modern parking problems can be solved by integrating biometric gate control with IoT-based parking management. The article discusses an Internet of Things-based smart parking system to improve vehicle access security and parking management. This system utilizes a Raspberry Pi 4 for automatic number plate and gate control. The solution guarantees a smooth parking experience and improves operational efficiency with ANPR for vehicle classification. The technique leverages cameras and ANPR software to recognize and record license plates, then correlates them to automate gate operation. IoT enables real-time monitoring, space accessibility, entries, and exits. BY classifying vehicles (e.g., personal, EV, emergency) and assigning places appropriately, the system promotes protection and operational effectiveness. It provides an affordable, adaptable, and flexible methodology that performs effectively in various situations, including shopping centers, workplaces, and apartment buildings. In addition to facilitating traffic and enhancing accessibility in urban areas, this automated method improves parking management's security and effectiveness. Biometric surveillance technologies can track suspicious activity in public spaces, identify known criminals, and promptly alert law enforcement. Consequently, our proposed system will be cost-effective, flexible, and scalable. We can use this framework in various environments such as malls, office buildings, residential complexes, etc. It offers a secure, efficient, and smart approach to modern parking management.

Future Work:

In the future, advanced machine learning and deep learning algorithms will be implemented to enable more accurate and faster detection of vehicle types and license plates. Additionally, predictive models will be developed to optimize parking space allocation based on historical data and real-time traffic patterns. We developed a mobile application that allows customers to view parking availability, reserve parking spaces in advance, and access parking via their devices.

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