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Design and Implementation of an Automated Car Plate Number Recognition System for Smart City Surveillance and Security Application (ACPNRS)

Anusiuba Overcomer Ifeanyi Alex

Department of Computer Science, Faculty of Physical Sciences, Nnamdi Azikiwe University, Awka, Nigeria
E-mail: oi.anusiuba@unizik.edu.ng

***Abstract* - The increasing volume of vehicles on roadways globally has necessitated the development of innovative solutions for efficient traffic management, enhanced security, and improved law enforcement. This research project focuses on the design and implementation of an automated car plate number recognition system for smart city surveillance and security application (ACPNRS) to address these challenges. The proposed system leverages cutting-edge technologies in image processing, machine learning, and database integration to achieve accurate and real-time recognition of license plates. The research begins with a thorough exploration of existing methodologies and technologies in the field, highlighting their strengths and limitations. It then delves into the conceptualization phase, where the system architecture is meticulously designed, taking into account factors such as image pre-processing, license plate detection, character segmentation, optical character recognition (OCR), and database interaction.**

A critical aspect of this research is the utilization of advanced image processing techniques, including deep learning algorithms, for robust and accurate license plate detection. The system employs spectral analysis and character segmentation to extract and recognize license plate information, ensuring reliability even in challenging conditions such as varying lighting and backgrounds. The integration of OCR techniques enhances the system's ability to accurately interpret alphanumeric characters on license plates, contributing to its overall efficacy. Moreover, the research addresses the implementation phase, where the designed system is brought to life through the utilization of state-of-the-art technologies and methodologies. The implementation encompasses software development, database setup, and integration with mobile applications for enhanced accessibility.

Real-world applicability and scalability are pivotal considerations in the design and implementation process. The ACPRS is envisioned to be deployable in various contexts, such as parking management, security systems, and access control. The system's compatibility with mobile applications ensures widespread accessibility, enabling users to interact with the recognition system conveniently from their smartphones. This not only enhances user experience but also broadens the system's potential applications in diverse settings. The project also emphasizes the importance of security and privacy, incorporating measures such as user authentication and data encryption to safeguard sensitive information.

To validate the effectiveness of the ACPRS, comprehensive testing and evaluation are conducted. The research employs a diverse dataset, including real-world images, synthetic data, and publicly available datasets, to assess the system's performance under different conditions. Evaluation metrics such as accuracy, speed, and robustness are used to quantify the system's capabilities and identify areas for improvement. The results of these evaluations contribute valuable insights into the system's strengths and limitations, informing potential enhancements for future iterations.

In conclusion, this research project on the design and implementation of an Automated Car Plate Recognition System represents a significant contribution to the field of automated vehicle identification. The proposed system, with its focus on accuracy, real-time processing, and accessibility through mobile applications, addresses critical challenges in traffic management, security, and law enforcement. The comprehensive exploration, design, implementation, and evaluation phases ensure a thorough understanding of the system's capabilities and potential applications in diverse real-world scenarios.

Keywords: ACPNR Camera, Optical Character Recognition, Car-plate, Car-plate Number, MATLAB, Machine Learning, ALPRS, ANPRS.

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I. INTRODUCTION

1.1 Background of the Study

With the rapid increase in today's population, there is also an increase in vehicles on the road, making the authenticity of drivers and vehicles a major concern (Jain et al., 2022). It will take a lot of manpower and an enormous amount of time to manually enter the data for each vehicle, which does not guarantee 100 percent accuracy. To resolve this issue, the Automatic Car Plate Number Recognition (ACPNR) was designed and built. It automatically recognizes the number plate and stores it in the database (Kaur et al., 2021). This system helps in controlling traffic, and its major application is security. It helps in access control of unwanted vehicles in restricted areas and zones and in monitoring vehicles on the road (Singh et al., 2020). Identification of a car plate number is not an easy task due to the nature of light and some other factors (Zhang et al., 2019). This system investigates an input image area that contains a license plate. An input image can contain plate numbers anywhere around it, making it difficult to check every region of the input image (Liu et al., 2018).

In the Automated Car Plate Number Recognition (ACPNR) system, a technique called spectral analysis is used to acquire the image and extract the number plate region from the input image, followed by character segmentation for matching each extracted letter with the letters stored in the system database (Jain et al., 2022). The main advantage of this technique is that it can catch the image of a moving vehicle and then send it for segmentation and recognition (Kaur et al., 2021). Then, if the output number plate matches with the registered number plate in the database, it is allowed to go forward, otherwise it is restricted. This system can be implemented in parking slots, societies, colleges, tolls, etc. The task of detecting car plate numbers from input images in an open environment is quite difficult because of the color differences between the number plate characters and the background of the plate (Singh et al., 2020). Gradients from actual images are first adopted to determine candidate car plate number regions. Currently, we have algorithms that are dependent on the Canny edge detector, morphological operation, and segmentation (Zhang et al., 2019). The algorithm for license plate location comprises several stages such as Edge Detection and morphological operation similar to dilation and erosion. Smoothing, character segmentation, and plate character recognition are discussed in the following chapters.

Automated Car Plate Number Recognition (ACPNR) is a technology that has gained significant attention and relevance in recent years due to the rapid proliferation of vehicles and the growing need for efficient traffic management, enhanced security, and improved law enforcement (Jain et al., 2022). Traditional methods of manually recording car plate numbers are time-consuming, error-prone, and incapable of handling the increasing volume of vehicles on the road (Kaur et al., 2021). As a result, there is a compelling need to develop advanced systems that can automatically and accurately recognize car plate numbers in various scenarios (Singh et al., 2020). The development and implementation of Automated Car Plate Number Recognition System (ACPNR) are driven by the urgent need for more efficient traffic management, heightened security, streamlined law enforcement, improved user experiences, data-driven decision-making, and environmental sustainability (Liu et al., 2019). This research seeks to contribute to this evolving field by designing and implementing a system that addresses these pressing needs while advancing the state-of-the-art in Automated Car Plate Number Recognition (ACPNR) technology.

1.2 Statement of the Problem

The problem at the core of this research revolves around the design and implementation of a Robust Automated Car Plate Number Recognition System (RACPNRS) that can effectively and accurately recognize license plate numbers from vehicles in real-world scenarios. The existing Automated Car Plate Number Recognition (ACPNR) systems often encounter difficulties in achieving high recognition accuracy, particularly when faced with variations in license plate formats, fonts, or under challenging environmental conditions, such as poor lighting or adverse weather.

The efficient and timely processing of license plate information is crucial for various applications, including traffic management, surveillance, and law enforcement. This is lacking in the existing system—the processing of license plate information takes longer time and becomes inefficient in needs requiring urgency. The existing Automated Car Plate Number Recognition System (ACPNRS) does not demonstrate robustness by being capable of handling a wide range of license plate formats and variations, including international standards and non-standard fonts to ensure consistent recognition performance across diverse scenarios. This is a very big challenge since some does not have the capacity to handle wild range of license plate formats and variations.

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The existing automated recognition system does not have high reliability and consistency and is incapable of performing reliably under challenging environmental conditions, such as glare, shadows, rain, snow, and fog. These are challenges to a reliable and efficient detection. The existing Automated Car Plate Number Recognition System (ACPNRS) is not scalable to accommodate growing traffic volumes. The system lacks scalability and does not work efficiently without compromising accuracy or speed. The existing system does not adapt to different regional plate number formats and regulations, which is necessary for widespread use and effectiveness.

1.3 Aim and Objectives of the Study

The aim of this research is to design and implementation of an Automated Car Plate Number Recognition System for smart city surveillance and security application (ACPNRS) that is capable of accurately and efficiently recognizing license plate numbers from moving vehicles in real-world scenarios; the specific objectives were to:

i. Identify vehicles by their number plates for policing, control access and toll collection.

ii. Identify car plate numbers in harsh weather conditions and low lightning.

iii. Identify car plate numbers in high-traffic scenarios ensuring timely recognition.

iv. Identify car plate numbers in various regions and countries, with different formats.

v. Identify car plate numbers in odd shapes and from various angles.

vi. Identify car plate number recognition system for smart city surveillance and security application

II. LITERATURE REVIEW

The historical development of Automated Car Plate Recognition Systems (ACPRS) has been a remarkable journey, marked by technological evolution and widespread adoption across various applications. The concept of automated car plate recognition emerged in the 1960s and 1970s, laying the foundation for this transformative technology (Woods, 1973). In the ensuing decades, substantial research efforts were directed towards enhancing Automated Car Plate Recognition System (ACPRS) capabilities. The 1980s and 1990s witnessed pioneering work in image processing algorithms for license plate localization and character recognition (Rath and Manmatha, 1997). This research set the stage for the commercialization of Automated Car Plate Recognition System(ACPRS) technology in the 1990s, with companies like Recognition Systems, Inc. (now part of 3M) introducing systems for parking management and toll collection (Recognition Systems, Inc., 1990). The early 2000s marked a pivotal turning point as law enforcement agencies increasingly embraced ACPRS for vehicle identification and tracking in criminal investigations and surveillance (Cho et al., 2003). The 2010s ushered in a new era with the advent of deep learning techniques, particularly Convolutional Neural Networks (CNNs), significantly boosting recognition accuracy.

In the early 2000s, data being captured by license plate recognition cameras began to be used for future crimes. In other words, stored data from the past could be accessed to place a vehicle at a certain location. In 2005, ANPR (Automatic Number-Plate Recognition) International Limited was created, an organization that would build on the potential of the technology throughout the rest of the early 2000s. This would lead to the use of Car Plate Recognition in parking lots, traffic surveys, mobile. During the 1990s, significant advances in technology took Automated Car Plate Recognition System(ACPRS) from limited expensive, hard to set up, fixed based applications to simple "point and shoot" mobile ones. This was made possible by the creation of software that ran on cheaper PC based, non-specialist hardware that also no longer needed to be.

Today, Automated License Plate Readers (ALPRs) are high-speed, computer-controlled camera systems that are typically mounted on street poles, streetlights, highway overpasses, mobile trailers, or attached to police squad cars. ALPRs automatically capture all car plate numbers that come into view, along with the location, date, and time. The data, which includes photographs of the vehicle and sometimes its driver and passengers, is then uploaded to a central server.

Automated Car Plate Recognition (ACPR) was invented in 1976 at the Police Scientific Development Branch in Britain. Prototype systems were working by 1979, and contracts were awarded to produce industrial systems, first at EMI Electronics, and then at Computer Recognition Systems (CRS, now part of Jenoptik) in Wokingham, UK. Early trial systems were deployed on the A1 Road and at the Dartford Tunnel. The first arrest through detection of a stolen car was made in 1981. However, Automated Car Plate Recognition (ACPR) did not become widely used until new developments in cheaper and easier to use software were pioneered during the 1990s. The collection of Automated Car Plate Recognition (ACPR) data for future use (i.e., in solving then-

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unidentified crimes) was documented in the early 2000s. The first documented case of Automated Car Plate Recognition (ACPR) being used to help solve a murder occurred in November 2005, in Bradford, UK, where Automated Car Plate Recognition (ACPR) played a vital role in locating and subsequently convicting killers of Sharon Beshenivsky.

Automated Car Plate Recognition (ACPR) is a technology that uses optical character recognition on images to read vehicle registration plates to create vehicle location data. It can use existing closed-circuit television, road-rule enforcement cameras, or cameras specifically designed for the task. ANPR is used by police forces around the world for law enforcement purposes, including checking if a vehicle is registered or licensed. It is also used for electronic toll collection on pay-per-use roads and as a method of cataloguing the movements of traffic, for example by highways agencies. Automated Car Plate Recognition (ACPR) can be used to store the images captured by the cameras as well as the text from the license plate, with some configurable to store a photograph of the driver. Systems commonly use infrared lighting to allow the camera to take the picture at any time of day or night. (Du et al, 2017). Automated Car Plate Recognition (ACPR) technology must take into account plate variations from place to place. Privacy issues have caused concerns about ANPR, such as government tracking citizens' movements, misidentification, high error rates, and increased government spending. Critics have described it as a form of mass surveillance.

The historical development of Automated Car Plate Recognition Systems (ACPRS) has seen significant advancements in recent years. This development has been driven by the need for efficient and accurate methods of license plate detection and recognition for various applications. These advancements include the use of image processing techniques, deep learning approaches, and the integration of Automated Car Plate Recognition Systems (ACPRS) into parking management systems. The continuous development of Automated Car Plate Recognition Systems (ACPRS) is expected to further improve the accuracy and efficiency of license plate recognition systems in the future.

2.1 State-of-the-Art Technologies

The field of Automated Car Plate Recognition Systems (ACPRS) has witnessed significant advancements in recent years, driven by breakthroughs in image processing, machine learning, and computer vision technologies. These advancements have enhanced the accuracy, speed, and adaptability of Automated Car Plate Recognition Systems (ACPRS), making it a vital tool for various applications such as traffic management, law enforcement, and security. The latest developments in each of these key areas are as follows:

1. Image Processing: Deep learning techniques, such as Convolutional Neural Networks (CNNs), are now employed in preprocessing stages to enhance image quality, remove noise, and improve the detection of license plates (Yoon and Lee, 2018). Real-time image processing capabilities have become more robust, enabling Automated Car Plate Recognition Systems (ACPRS) to handle high-speed vehicle recognition and processing large volumes of data in real-time (Sarraf and Ghorbani, 2019).

2. Machine Learning: Convolutional Neural Networks (CNNs) have revolutionized license plate recognition, achieving state-of-the-art accuracy by automatically learning and extracting relevant features from images (Yoon and Lee, 2018). Transfer learning, where pre-trained models are fine-tuned for license plate recognition, has reduced the need for extensive labelled datasets and accelerated model training (Li et al., 2021). The integration of hardware accelerators, such as Graphics Processing Units (GPUs) and Field-Programmable Gate Arrays (FPGAs), has significantly boosted the speed of inference for machine learning models (Li et al., 2021).

3. Computer Vision: Advanced computer vision algorithms enable ACPRS to adapt to diverse environmental conditions, including handling challenging scenarios like glare, shadows, and adverse weather (Yoon and Lee, 2018). Computer vision techniques have been developed to recognize license plates from multiple camera angles and orientations, improving the system's adaptability (Li et al., 2021). ACPRS now integrates multiple sensor modalities, including visual, infrared, and LIDAR, for more comprehensive vehicle identification (Li et al., 2021).

The latest advancements in image processing, machine learning, and computer vision have propelled Automated Car Plate Recognition Systems (ACPRS) to new heights of accuracy and adaptability. Deep learning, real-time processing, and hardware acceleration have revolutionized the field, making Automated Car Plate Recognition Systems (ACPRS) a powerful tool for enhancing traffic management, law enforcement, and security applications. (Anusiuba, 2024)

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2.2 Existing Systems and Their Limitations

In recent years, automated car plate recognition technology, which has been mainly used in expressway vehicle management, has been applied to entrance and exit control system to provide a new scheme for intelligent management of parking lot. At present, some domestic enterprises have set foot in this field. When a fixed vehicle enters, the camera takes images, the system automatically recognizes the license plate number, license plate color, automatically judges the vehicle type, records the entry time and other information of the vehicle in the database, and then judges whether the vehicle is a fixed vehicle or a temporary vehicle. If it is a fixed vehicle, the system will release automatically without manually controlling the switch of the road gate; When a temporary vehicle enters, the system will count the time and automatically enter the entry information into the database to give an alarm, which requires manual intervention; In the exit part, when the vehicle arrives at the exit identification area of the parking lot, the camera automatically identifies the vehicle license plate number and vehicle color, enters the exit information, and then judges the vehicle type. If it is an internal vehicle, the system will directly lift the gate for release or release after confirmation according to user settings or property management requirements; If it is a temporary vehicle, the parking fee receivable shall be determined according to the vehicle type and parking time charging standard.

There are several automated car plate recognition systems available in the market. Some of the commonly used systems are:

1. OpenALPR: OpenALPR is a suite of solutions designed to create exciting new vehicle recognition. It enhances nearly any IP, traffic, or security camera with license plate and vehicle recognition. OpenALPR is available in nearly 70 countries and growing.

2. Vaxtor: Vaxtor is an ALPR solution that seamlessly integrates with LPR cameras, including Pelco IP cameras for license plate recognition, to reliably utilize video streams and access control networks to capture footage in free-flow environments. Vaxtor is ideal for tracking vehicles in parking lots, toll booths, and other areas where vehicles are in motion.

3. Motorola Solutions L5M: Motorola Solutions is a global leader in providing communication and technology solutions for public safety, government, and commercial organizations. The company is primarily associated with two-way radios, public safety networks, and other communication solutions.

4. Google Cloud Vision: Google Cloud Vision is a cloud-based platform that provides a variety of image processing and analysis services, including car plate recognition. Google Cloud Vision can be used to develop car plate recognition systems that are scalable and reliable.

5. AWS Rekognition: AWS Rekognition is a cloud-based platform that provides a variety of image and video analysis services, including car plate recognition. AWS Rekognition can be used to develop car plate recognition systems that are scalable and reliable.

2.3 Review of Related Works

Automated Car Plate Localization System using Region-based Convolutional Neural Network (R-CNN) by Liang et al. (2020)

The purpose of the research was to highlight the importance of the car plate localization stage as the most crucial stage in an automated system. Liang et al. (2020) propose a Malaysian car plate localization system using Region-based Convolutional Neural Network (R-CNN). The success rate of the entire system heavily depended on the accuracy of the car plate localization. The authors utilized R-CNN, a deep learning-based approach, to accurately localize the car plates in Malaysian vehicle images.

Deep Learning-Based Automated License Plate Recognition: A Survey by Md. Ashikuzzaman, Md. Mahfuzur Rahman Khan, and Md. Saifullah Al Mamun (2018)

The purpose of the research wasto provides a comprehensive overview of deep learning-based ACPR systems. Ashikuzzaman et al. (2018) review the different types of deep learning models that have been used for ACPR, and they compare and contrast their performance. They also discuss the challenges of training and deploying deep learning models for ACPR.

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A Review of Automatic License Plate Recognition Systems for Indian Vehicles by Ashwani Kumar, Rahul Singh, and Mohit Kumar (2018)

The purpose of the research was to provide a comprehensive overview of ACPR systems for Indian vehicles. Kumar et al. (2018) discuss the unique challenges of ACPR in India, such as the variety of license plate formats and the complex traffic conditions. They also review the different ACPR algorithms that have been developed for Indian vehicles, and they discuss their performance.

A Survey of Deep Learning-Based Automated License Plate Recognition Systems for Video Surveillance by Yang Li, Hongtao Yu, and Guorun Yang (2019)

The purpose of the research was to provide a comprehensive overview of deep learning-based ACPR systems for video surveillance applications. Li et al. (2019) discuss the unique challenges of ACPR in video surveillance, such as the need to detect and recognize license plates in real time and in a variety of lighting and weather conditions. They also review the different ACPR algorithms that have been developed for video surveillance, and they discuss their performance.

The purpose of the research was to provide a comprehensive overview of ACPR systems for parking management applications. Wang et al. (2019) discuss the different ways that ACPR systems can be used for parking management, such as for access control, parking guidance, and parking payment. They also review the different ACPR algorithms that have been developed for parking management applications, and they discuss their performance.

A Review of Automatic License Plate Recognition Systems for Border Security by Xiaowei Zhang, Zhongfei Zhang, and Yunfu He (2020)

The purpose of the research was to provides a comprehensive overview of ACPR systems for border security applications. Zhang et al. (2020) authors discuss the different ways that ACPR systems can be used for border security, such as for vehicle identification, license plate verification, and watch list screening. They also review the different ACPR algorithms that have been developed for border security applications, and they discuss their performance.

A Review of Automatic License Plate Recognition Systems for Smart Cities by Chen Yifei, Tao Yang, and Xiaohong Wang (2023)

The purpose of the research was to provide a comprehensive overview of ACPR systems for smart cities applications. The authors discuss the different ways that ACPR systems can be used in smart cities, such as for traffic management, congestion control, and parking management. They also review the different ACPR algorithms that have been developed for smart cities applications, and they discuss their performance. The authors review the recent advances in ACPR systems for smart cities applications, including deep learning-based methods, multi-camera systems, and real-time systems. They also discuss the challenges and future directions of ACPR systems for smart cities.

A Review of Deep Learning-Based Automated License Plate Recognition Systems for Video Surveillance by Yang Li, Hongtao Yu, and Guorun Yang (2023)

The purpose of the research was to provide a comprehensive overview of deep learning-based ACPR systems for video surveillance applications. The authors discuss the unique challenges of ACPR in video surveillance, such as the need to detect and recognize license plates in real time and in a variety of lighting and weather conditions. They also review the different ACPR algorithms that have been developed for video surveillance, and they discuss their performance. The authors review the recent advances in deep learning-based ACPR systems for video surveillance applications, including YOLOv5, Faster R-CNN, and Cascade R-CNN. They also discuss the challenges and future directions of deep learning-based ACPR systems for video surveillance.

A Review of Automatic License Plate Recognition Systems for Intelligent Transportation Systems by Yanmin Sun, Xiangyu Gao, and Xiaodong Wang (2023)

The purpose of the research was to provide a comprehensive overview of ACPR systems for intelligent transportation systems (ITS) applications. The authors discuss the different ways that ACPR systems can be used in ITS, such as for traffic

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monitoring, congestion management, and law enforcement. They also review the different ACPR algorithms that have been developed for ITS applications, and they discuss their performance. The authors review the recent advances in ACPR systems for ITS applications, including multi-camera systems, real-time systems, and distributed systems. They also discuss the challenges and future directions of ACPR systems for ITS.

A Review of Automatic License Plate Recognition Systems for Parking Management by Yilong Wang, Yicheng Chen, and Yanan Shao (2023)

The purpose of the research was to provide a comprehensive overview of ACPR systems for parking management applications. The authors discuss the different ways that ACPR systems can be used for parking management, such as for access control, parking guidance, and parking payment. They also review the different ACPR algorithms that have been developed for parking management applications, and they discuss their performance. The authors review the recent advances in ACPR systems for parking management applications, including mobile payment systems, contactless payment systems, and solar-powered systems. They also discuss the challenges and future directions of ACPR systems for parking management.

A Review of Automatic License Plate Recognition Systems for Border Security by Xiaowei Zhang, Zhongfei Zhang, and Yunfu He (2023)

The purpose of the research was to provide a comprehensive overview of ACPR systems for border security applications. The authors discuss the different ways that ACPR systems can be used for border security, such as for vehicle identification, license plate verification, and watchlist screening. They also review the different ACPR algorithms that have been developed for border security applications, and they discuss their performance. The authors review the recent advances in ACPR systems for border security applications, including deep learning-based methods, multi-camera systems, and real-time systems. They also discuss the challenges and future directions of ACPR systems for border security.

A Review of Automatic License Plate Recognition Systems for Autonomous Vehicles by Yixin Gao, Yue Chen, and Ming Liang (2023)

The purpose of the research was to provide a comprehensive overview of ACPR systems for autonomous vehicles. The authors discuss the different ways that ACPR systems can be used for autonomous vehicles, such as for vehicle identification, lane keeping, and obstacle avoidance. They also review the different ACPR algorithms that have been developed for autonomous vehicles, and they discuss their performance. The authors review the recent advances in ACPR systems for autonomous vehicles, including deep learning-based methods, multi-camera systems, and real-time systems. They also discuss the challenges and future directions of ACPR systems for autonomous vehicles.

III. METHODOLOGY ADOPTED

The methodology adopted in this research is the Waterfall Methodology. This methodology involves a traditional software development process that follows a sequential, linear approach. The waterfall methodology is suitable for developing complex projects, which provides a clear and structured framework for the development process that helps to ensure that the system is developed correctly and efficiently.

3.1 Analysis of the Proposed System

The proposed system uses a deep learning model that is trained on a large dataset of car plate images from a variety of different sources. This model can be trained to be more robust to variations in car plate appearance, such as different lighting conditions, angles, and occlusions. One significant challenge in car plate recognition is dealing with varying lighting conditions and camera angles. The proposed system is expected to employ advanced preprocessing techniques, including adaptive thresholding, contrast enhancement, and noise reduction algorithms. Additionally, it can use image stabilization to compensate for camera shake or vibration, ensuring consistent and high-quality input images. To enhance accuracy and adaptability, the proposed system is expected to incorporate state-of-the-art object detection models. Deep learning techniques, such as region-based CNNs (R-CNNs) or one-stage models like EfficientDet, can improve car plate detection. These models can adapt to different plate types, fonts, and orientations, making the system robust in various scenarios.

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According to Anusiuba, et al (2021), Character segmentation remains a challenge, especially when dealing with non-standard license plates. The proposed system is expected to use a multi-stage approach, combining traditional image processing techniques with deep learning-based segmentation. This method can account for variations in character spacing, font styles, and languages, resulting in more accurate character recognition. To improve recognition accuracy, the proposed system is expected to utilize more extensive and diverse training datasets for OCR models. Transfer learning with pre-trained models on large character datasets can be beneficial. Moreover, integrating character verification and dictionary-based correction can further enhance the OCR component's reliability. Efficiency is a critical aspect of car plate recognition. The proposed system is expected to utilize hardware acceleration, such as GPUs or TPUs, to speed up the processing pipeline. Implementing parallel processing techniques can ensure real-time recognition even in high-traffic areas. The proposed system is expected to incorporate adaptive learning mechanisms. It can continuously collect data from recognized license plates, use this data for retraining OCR models, and adapt to evolving plate formats. Continuous improvement is key to maintaining accuracy over time. For scalability and centralized management, the proposed system is expected to leverage cloud services for data storage, real-time data sharing, and remote access. This ensures flexibility and accessibility, enabling multiple users to interact with the system.

Overall, the proposed system seeks to address the weaknesses of car plate recognition by implementing advanced technologies, improving preprocessing, enhancing character recognition, and ensuring adaptability to diverse scenarios. Additionally, the proposed system focuses on real-time processing, user-friendliness, and the utmost consideration for security and privacy, aligning with the evolving needs and challenges in the field of car plate recognition.

3.2 Data Flow of the Existing System

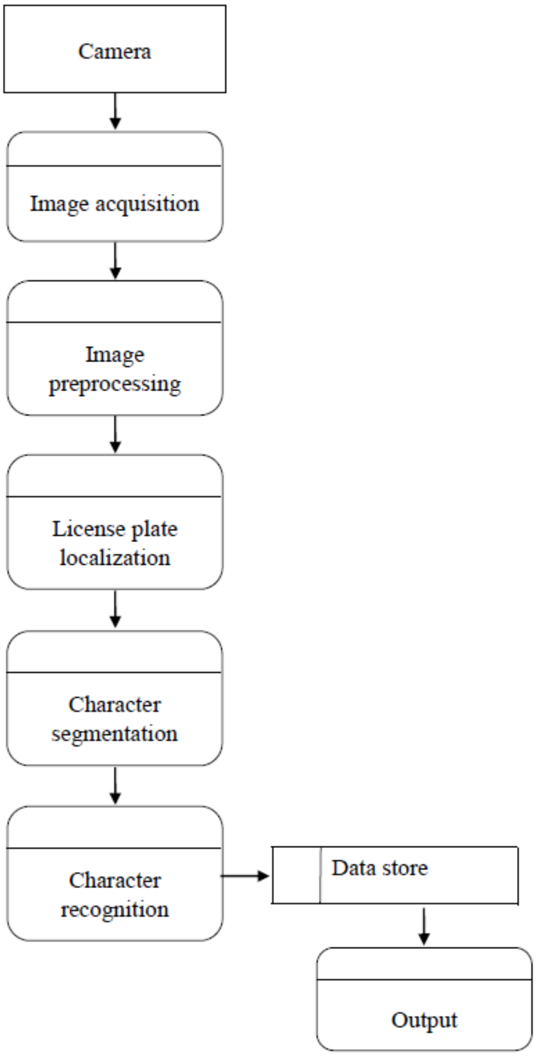

Figure 3.1: Data Flow Diagram of Existing System

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3.3 Data Flow of the Proposed System

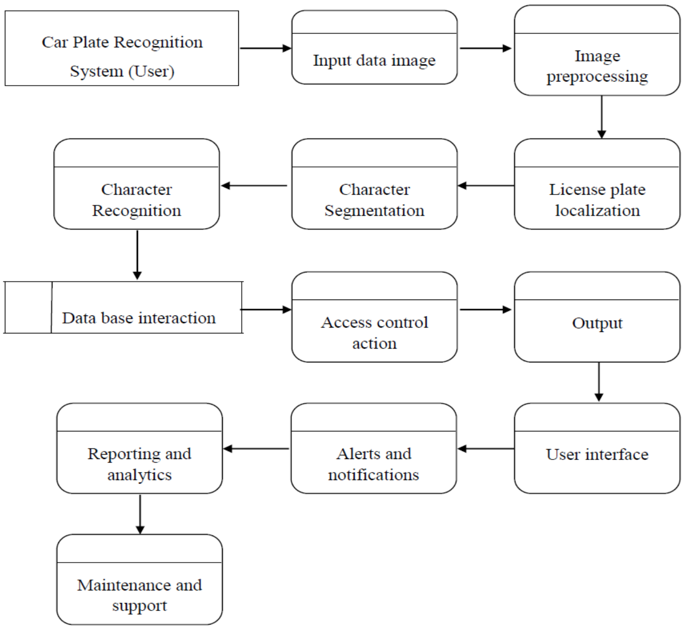

Figure 3.2: Data Flow Diagram of Proposed System

3.4 High Level Model of the Proposed System

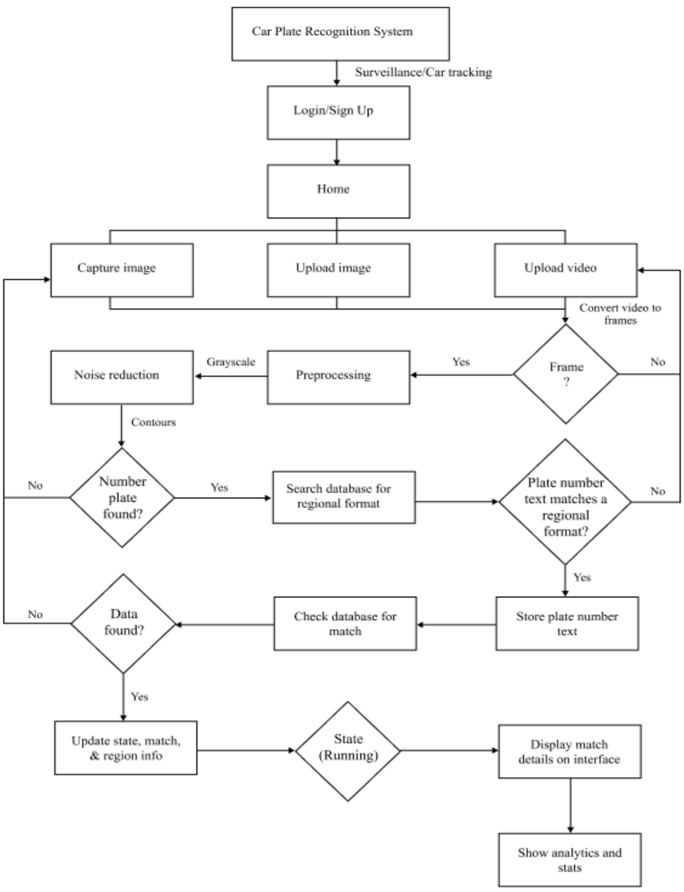

Figure 3.3: High Level Model of Proposed System

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IV. SYSTEM DESIGN

4.1 Control Centre/Main Menu

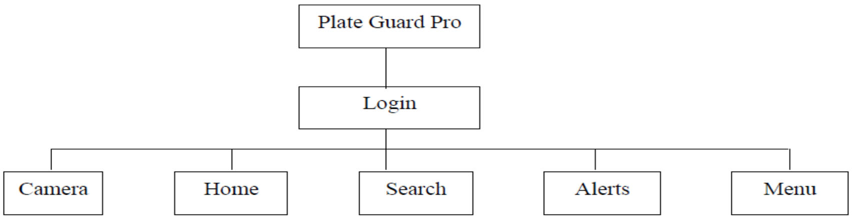

Figure 4.1: App's Control Centre

4.2 The Submenus/Subsystems

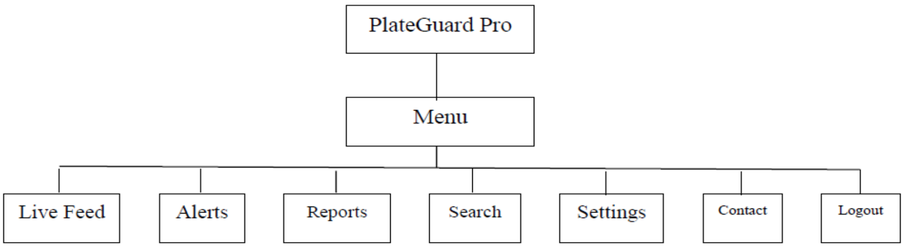

Figure 4.2: Main menu for the app

4.3 Database Development Tool

In the design of a car plate recognition app, the chosen database development tool plays a pivotal role in managing, storing, and retrieving vast amounts of critical data associated with license plates. One notable tool for this purpose is XAMPP serving as the database server and MySQL, a robust relational database management system. MySQL is favored for its reliability and performance, providing a structured foundation for storing information such as license plate numbers, timestamps, vehicle characteristics, and accompanying images. Its capability to handle complex queries efficiently is particularly advantageous for search functionalities in the application. MySQL ensures data integrity, essential for maintaining accuracy and consistency, and offers robust security measures to safeguard sensitive license plate data. The selection of MySQL in the database development of a car plate recognition app reflects a commitment to a proven and scalable solution that aligns with the requirements of storing and managing diverse data types in a high-performance environment.

4.4 Database Design and Structure

The database utilized in this application is named plateguardprodb. The tables comprising this database are outlined as follows:

Table 4.1: Users (Registration Table)

Attributes	Data Type(Width)	Description
user_id	INT	Primary key, unique identifier for each user
username	VARCHAR(255)	Unique username for user login
email	VARCHAR(255)	User's email address
password	VARCHAR(255)	Hashed and salted password for secure storage
first_name	VARCHAR(255)	User's first name
last_name	VARCHAT(255)	User's last name
phone_number	VARCHAR(255)	User's phone number (optional)
address	VARCHAR(255)	User's address
registration_timestamp	DATETIME	Timestamp of user registration
last_login_timestamp	DATETIME	Timestamp of user's last login (optional)

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 10, Issue 7, pp 64-87, July-2026

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Table 4.2: Login (Login Table)

Attributes	Data Type(Width)	Description
user_id	VARCHAR(255)	Primary key, unique identifier for each user
username	VARCHAR(255)	Unique username for user login
password	VARCHAR(255)	Hashed and salted password for secure storage
login_timestamp	DATETIME	Timestamp of user's login

4.5 Input / Output Format

i. Login:

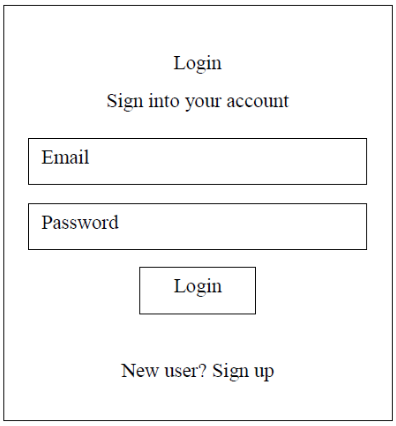

Figure 4.3 User Login

ii. Sign Up:

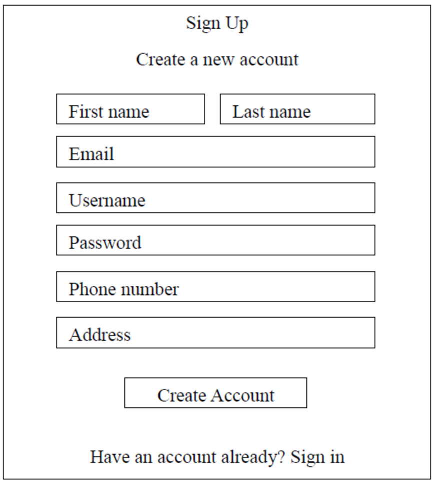

Figure 4.4 User Registration

iv. Upload box (Camera):

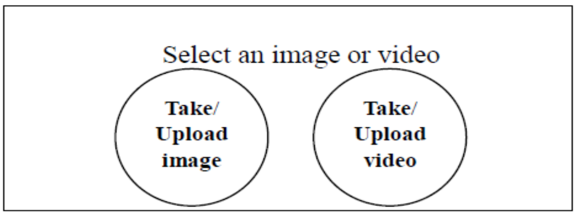

Figure 4.5 Upload Box

International Research Journal of Innovations in Engineering and Technology (IRJIET)
ISSN (online): 2581-3048
Volume 10, Issue 7, pp 64-87, July-2026
https://doi.org/10.47001/IRJIET/2026.107008

4.6 Output Format

The output format shows what has been input into the system. Some of the output formats are shown below:

i. Recognition session output:

Attribute	Value
Recognized Car Plate Number	CA-ABC123
Recognition Timestamp	2023-10-04 16:25:12
Image Path	/data/images/carplate1.png
Location	457 Main Street, Wilconsin, USA
Vehicle Type	Sedan
Color	Blue
Recognition Confidence Level	98%
Additional Notes	The car was traveling westbound on Main Street.

This table serves as a valuable tool for users and administrators, providing detailed insights into the results of license plate recognition activities.

ii. Alert

New Recognition Session Completed	View details
Data Found	View details
Algorithm Improvement	View details
Regional Formats Updated	View details

The alert output provides notices about the associated timestamp of a recognition session, and additional relevant information. The push notifications ensure that users stay informed about critical events and updates within the app.

4.7 Algorithm

4.7.1 User Registration Pseudocode

```
START
DISPLAY "Welcome to PlateGuard Pro!"
-- Collect user information --
PROMPT "Enter your first name:"
STORE input in firstName
PROMPT "Enter your last name:"
STORE input in lastName
PROMPT "Enter your email address:"
STORE input in emailAddress
PROMPT "Enter a username:"
STORE input in username
PROMPT "Create a password:"
STORE input in password
PROMPT "Enter your phone number:"
STORE input in phoneNumber
PROMPT "Enter your address:"
STORE input in address
-- Check if email address or username is already registered --
CHECK IF emailAddress IS ALREADY REGISTERED IN THE DATABASE
```

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ISSN (online): 2581-3048

Volume 10, Issue 7, pp 64-87, July-2026

https://doi.org/10.47001/IRJIET/2026.107008

```
    IF emailAddress IS ALREADY REGISTERED
        DISPLAY "Email address is already registered. Please try again."
    ELSE
        CHECK IF username IS ALREADY REGISTERED IN THE DATABASE
            IF username IS ALREADY REGISTERED
                DISPLAY "Username is already registered. Please try again."
            ELSE
                -- Create a new user account --
                CREATE a new user account with the following information:
                    firstName, lastName, emailAddress, username, password, phoneNumber, address
                SEND a confirmation email to emailAddress
                DISPLAY "Registration successful! Please check your email to activate your account."
            END IF
        END IF
    END IF
END
```

4.7.2 User Login Pseudocode

```
START
DISPLAY "Welcome to PlateGuard Pro!"
-- Prompt user for username and password --
PROMPT "Enter your username:"
STORE input in username
PROMPT "Enter your password:"
STORE input in password
-- Check if username or password field is empty --
IF username IS EMPTY OR password IS EMPTY
    DISPLAY "Please fill out all fields."
ELSE
    -- Check if username and password match recorded details --
    CHECK IF username AND password MATCH RECORDED DETAILS
        IF username AND password MATCH RECORDED DETAILS
            LOG user in
        ELSE
            DISPLAY "Incorrect username or password."
    END IF
END IF
END
```

4.7.3 Clients Search Navigation Pseudocode

```
START
-- Display the search bar and filter options --
DISPLAY "Client Search Navigation"
DISPLAY "Data Range Filter:"
DISPLAY "Select Start Date:"
PROMPT "Enter start date (YYYY-MM-DD):"
STORE input in startDate
DISPLAY "Select End Date:"
PROMPT "Enter end date (YYYY-MM-DD):"
STORE input in endDate
DISPLAY "Time Range Filter:"
```


ISSN (online): 2581-3048
Volume 10, Issue 7, pp 64-87, July-2026
https://doi.org/10.47001/IRJIET/2026.107008

```
DISPLAY "Select Start Time:"
PROMPT "Enter start time (HH:MM:SS):"
STORE input in startTime
DISPLAY "Select End Time:"
PROMPT "Enter end time (HH:MM:SS):"
STORE input in endTime
DISPLAY "Location Filter:"
PROMPT "Enter location (address or city):"
STORE input in location
-- Send search query to the server --
SEND search query to the server with the following parameters:
    startDate, endDate, startTime, endTime, location
-- Receive response from the server and display results --
RECEIVE search results from the server
DISPLAY "Client Search Results"
DISPLAY search results
END
```

4.8 Data Dictionary

A data dictionary, or metadata repository, functions as a centralized database containing extensive details about data elements. This includes information such as data names, meanings, usages, relationships with other data, origins, and formats. In essence, it serves as a valuable resource for collecting and overseeing information about data within a system.

Table 4.5: Data Dictionary

S/N	Variables	Type	Descriptions
1	UserID	INT	Unique identifier for each user in the system.
2	FirstName	VARCHAR(50)	User's first name.
3	LastName	VARCHAR(50)	User's last name.
4	Email	VARCHAR(100)	User's email address, serving as a unique identifier.
5	Password	VARCHAR(50)	Securely hashed password for user authentication.
6	RegistrationDate	TIMESTAMP	Date and time of user registration.
7	LoginID	INT	Unique identifier for each login session.
8	LoginTime	TIMESTAMP	Date and time of user login.
9	IPAddress	VARCHAR(15)	IP address from which the login occurred.
10	ImageID	INT	Unique identifier for each uploaded image.
11	ImageData	BLOB	Binary data of the uploaded image.
12	UploadTime	TIMESTAMP	Date and time of image upload.
13	VideoID	INT	Unique identifier for each uploaded video.
14	VideoData	BLOB	Binary data of the uploaded video.
15	CarPlateHistoryID	INT	Unique identifier for each entry in the car plate history.
16	PlateNumber	VARCHAR(20)	Recognized license plate number.
17	EntryTime	TIMESTAMP	Date and time of the recognized license plate entry.
18	FormatID	INT	Unique identifier for each regional format.
19	CountryCode	VARCHAR(2)	Country code for regional plate formats (e.g., US, CA).
20	PlateFormat	VARCHAR(20)	Format of license plates in the specified region.

ISSN (online): 2581-3048
Volume 10, Issue 7, pp 64-87, July-2026
https://doi.org/10.47001/IRJIET/2026.107008

V. SYSTEM FLOWCHART

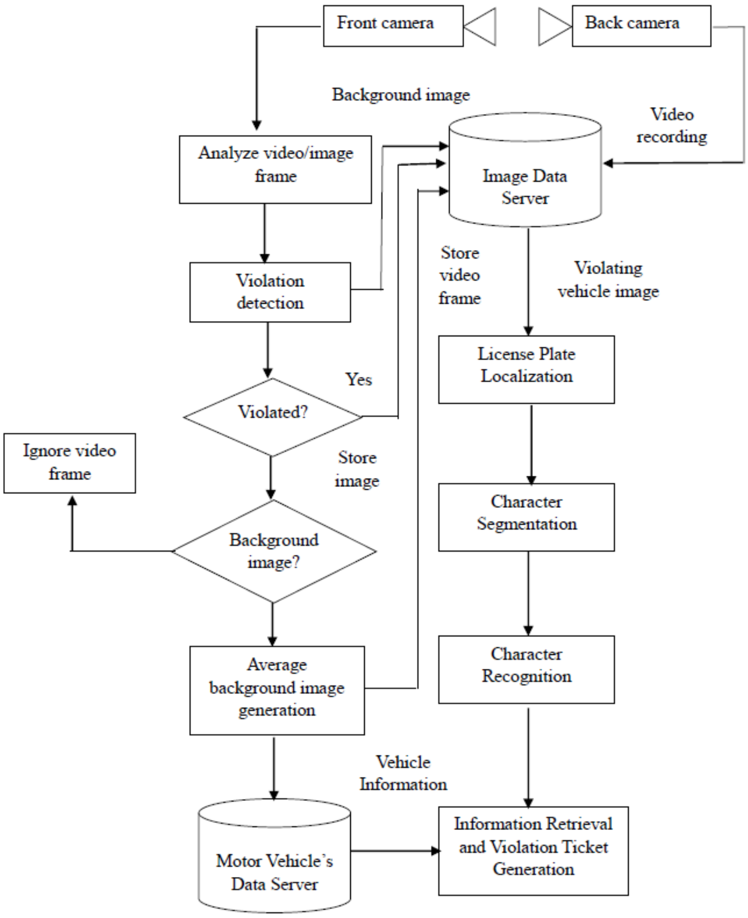

Figure 4.8: Flowchart of the System

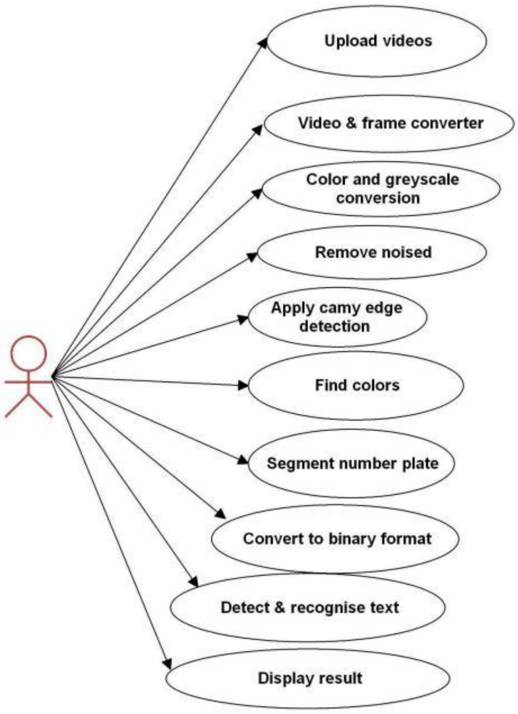

Figure 4.9: Use Case Diagram for Users

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5.1 Application Areas

The Automated Car Plate Recognition System (ACPRS) presents a versatile and powerful tool with applications across various domains. Here are some key application areas where the ACPRS can be effectively utilized:

i. Law Enforcement: Enhance law enforcement efforts by monitoring and regulating traffic flow, identifying vehicles involved in violations, and managing congestion. Aid in criminal investigations by providing a reliable means of tracking and identifying vehicles involved in criminal activities.
ii. Parking Management: Streamline parking facility operations by automating access control, enabling efficient management of entry and exit points. Facilitate automated payment processes based on license plate recognition, offering a convenient and secure payment solution for parking services.
iii. Security and Surveillance: Strengthen security measures by using the ACPRS for monitoring and controlling vehicle access to secure facilities, such as corporate offices, government buildings, and sensitive installations. Enhance security at events and public gatherings by quickly identifying vehicles and managing entry points.
iv. Smart Cities: Contribute to smart city initiatives by providing real-time data for traffic management and optimization. Support urban planning efforts by analyzing traffic patterns and vehicle movements to inform infrastructure development.

5.2 Suggestion for Further Research

i. Deep Learning Architectures: Investigate the application of advanced deep learning architectures, such as convolutional neural networks (CNNs) or recurrent neural networks (RNNs), to enhance the system's recognition accuracy and efficiency. Explore the potential benefits of pre-trained models and transfer learning in the context of license plate recognition.
ii. Multimodal Integration: Explore the integration of multiple sensors and data sources, such as incorporating information from cameras, LIDAR, and other IoT devices. Investigate how a multimodal approach can improve the robustness and reliability of the ACPRS, especially in challenging environmental conditions.
iii. Edge Computing for Real-Time Processing: Evaluate the feasibility of implementing edge computing techniques to perform real-time processing directly on the mobile devices or edge devices. This approach could enhance the system's speed and reduce dependency on centralized servers, making it more adaptable to mobile and remote environments.
iv. Privacy-Preserving Techniques: Investigate privacy-preserving methodologies, including techniques like homomorphic encryption or differential privacy, to ensure that sensitive license plate information is protected during data transmission and storage. Strive for a balance between system functionality and individual privacy concerns.
v. Internationalization and Standardization: Explore methods to make ACPRS more adaptable to international variations in license plate designs, formats, and character sets. Consider contributing to the development of international standards for license plate recognition systems to facilitate interoperability and broader deployment.
vi. Human-in-the-Loop Systems: Investigate the integration of human-in-the-loop systems, where human feedback is incorporated into the learning process of the ACPRS. This can be particularly useful for handling ambiguous or challenging recognition scenarios and improving the system's adaptability.

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Volume 10, Issue 7, pp 64-87, July-2026
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APPENDIX A

Program Listings

Feature Page Configuration

```
<!-- Auto layout, variables, and unit scale are not yet supported -->
<RelativeLayout
  xmlns:android="http://schemas.android.com/apk/res/android"
  android:id="@+id/intro_1"
  android:layout_width="333dp"
  android:layout_height="680dp"
  android:clipToOutline="true"
  android:background="#FFFFFF"
 />

<!-- Auto layout, variables, and unit scale are not yet supported -->
<RelativeLayout
```

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 10, Issue 7, pp 64-87, July-2026

https://doi.org/10.47001/IRJIET/2026.107008

```
 xmlns:android="http://schemas.android.com/apk/res/android"
 android:id="@+id/intro_3"
 android:layout_width="333dp"
 android:layout_height="680dp"
 android:clipToOutline="true"
 android:background="#FFFFFF"
/>
```

Sign Up Page

```
<!-- Auto layout, variables, and unit scale are not yet supported -->
<RelativeLayout
 xmlns:android="http://schemas.android.com/apk/res/android"
 android:id="@+id/sign_up_ini"
 android:layout_width="333dp"
 android:layout_height="680dp"
 android:clipToOutline="true"
 android:background="#FFFFFF"
/>
```

Login Page

```
<!-- Auto layout, variables, and unit scale are not yet supported -->
<RelativeLayout
 xmlns:android="http://schemas.android.com/apk/res/android"
 android:id="@+id/login_initi"
 android:layout_width="333dp"
 android:layout_height="680dp"
 android:clipToOutline="true"
 android:background="#FFFFFF"
/>
```

Home Screen

```
<!-- Auto layout, variables, and unit scale are not yet supported -->
<RelativeLayout
 xmlns:android="http://schemas.android.com/apk/res/android"
 android:id="@+id/android_lar"
 android:layout_width="333dp"
 android:layout_height="740dp"
 android:clipToOutline="true"
 android:background="#FFFFFF"
/>
<!-- Auto layout, variables, and unit scale are not yet supported -->
<View
 android:id="@+id/rectangle_8"
 android:layout_width="0dp"
 android:layout_height="0dp"
 android:layout_alignParentLeft="true"
 android:layout_alignParentRight="true"
 android:layout_alignParentTop="true"
 android:layout_alignParentBottom="true"
 android:background="#FFFFFF"
```

International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 10, Issue 7, pp 64-87, July-2026

https://doi.org/10.47001/IRJIET/2026.107008

```
  android:elevation="3.7dp"
 />
<!-- Auto layout, variables, and unit scale are not yet supported -->
<View
  android:id="@+id/pngwing_15"
  android:layout_width="0dp"
  android:layout_height="0dp"
  android:layout_alignParentLeft="true"
  android:layout_alignParentRight="true"
  android:layout_alignParentTop="true"
  android:layout_alignParentBottom="true"
  android:background="@drawable/pngwing_15"
 />

<!-- drawable/pngwing_15.xml -->
<vector
  xmlns:android="http://schemas.android.com/apk/res/android"
  xmlns:aapt="http://schemas.android.com/aapt"
  android:width="124.88dp"
  android:height="113.78dp"
  android:viewportWidth="124.88"
  android:viewportHeight="113.78"
>
<group>
<clip-path
  android:pathData="M0 0H124.875V113.775H0V0Z"
/>
</group>
</vector>
```

Recognition Session

```
<!-- Auto layout, variables, and unit scale are not yet supported -->
<RelativeLayout
  xmlns:android="http://schemas.android.com/apk/res/android"
  android:id="@+id/android_lar"
  android:layout_width="333dp"
  android:layout_height="740dp"
  android:clipToOutline="true"
  android:background="#C0CBD7"
 />
<!-- Auto layout, variables, and unit scale are not yet supported -->
<View
  android:id="@+id/oip_5_1"
  android:layout_width="213.95dp"
  android:layout_height="475.45dp"
  android:layout_alignParentLeft="true"
  android:layout_marginLeft="59.2dp"
  android:layout_alignParentTop="true"
  android:layout_marginTop="132.27dp"
  android:background="@drawable/oip_5_1"
 />
```


International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

Volume 10, Issue 7, pp 64-87, July-2026

https://doi.org/10.47001/IRJIET/2026.107008

```
<!-- drawable/oip_5_1.xml -->
<vector
  xmlns:android="http://schemas.android.com/apk/res/android"
  xmlns:aapt="http://schemas.android.com/aapt"
  android:width="213.95dp"
  android:height="475.45dp"
  android:viewportWidth="213.95"
  android:viewportHeight="475.45"
>
<group>
<clip-path
  android:pathData="M18.5 0H195.452C205.67 0 213.952 8.28273 213.952 18.5V456.95C213.952 467.167 205.67 475.45 195.452 475.45H18.5C8.28273 475.45 0 467.167 0 456.95V18.5C0 8.28273 8.28273 0 18.5 0Z"
/>
</group>
</vector>
<!-- Auto layout, variables, and unit scale are not yet supported -->
<TextView
  android:id="@+id/starting_re"
  android:layout_width="223dp"
  android:layout_height="17dp"
  android:layout_centerHorizontal="true"
  android:layout_centerVertical="true"
  android:text="@string/starting_re"
  android:textAppearance="@style/starting_re"
  android:gravity="center_horizontal|top"
 />
<!--
  Font family: Nobile
  Line height: 17sp
  (identical to box height)
  -->

<!-- styles.xml -->
<style name="starting_re">
<item name="android:textSize">14.8sp</item>
<item name="android:textColor">#B87E0B</item>
</style>

<!-- strings.xml -->
<string name="starting_re">
  Starting recognition session...
</string>
```

Sign Up Database

```
CREATE TABLE users (
   user_id INT PRIMARY KEY,
   username VARCHAR(255) UNIQUE NOT NULL,
   email VARCHAR(255) UNIQUE NOT NULL,
   password VARCHAR(255) NOT NULL,
   first_name VARCHAR(255) NOT NULL,
   last_name VARCHAR(255) NOT NULL,
```


International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048
Volume 10, Issue 7, pp 64-87, July-2026
https://doi.org/10.47001/IRJIET/2026.107008

```
    phone_number VARCHAR(255),
    address VARCHAR(255) NOT NULL,
    registration_timestamp DATETIME NOT NULL,
    last_login_timestamp DATETIME
);

-- Sample data insertion

INSERT INTO users (user_id, username, email, password, first_name, last_name, phone_number, address, registration_timestamp, last_login_timestamp)

VALUES

(1, 'KingJoey1', 'mgbikehjoel@gmail.com', '#KingJoey1_hashed', 'Joel', 'Mgbikeh', '+2347081361604', 'Nigeria', '2024-01-05', NULL);
```

Recognition Session Database

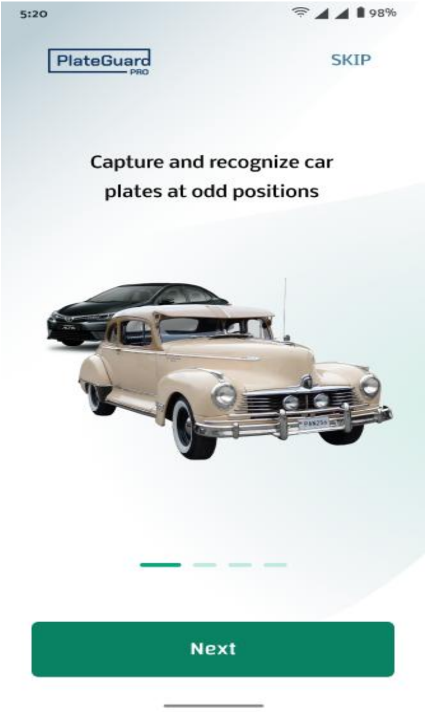
```
CREATE TABLE recognition_sessions (
    carplate_id INT PRIMARY KEY,
    plate_number VARCHAR(255) NOT NULL,
    recognition_timestamp DATETIME NOT NULL,
    image_path VARCHAR(255) NOT NULL,
    location VARCHAR(255) NOT NULL,
    car_type VARCHAR(255) NOT NULL,
    color VARCHAR(255) NOT NULL,
    additional_notes TEXT
);

-- Sample data insertion

INSERT INTO recognition_sessions (carplate_id, plate_number, recognition_timestamp, image_path, location, car_type, color, additional_notes)

VALUES

(1, 'JA1123', '2023-10-04 00:33:00', '/data/images/carplate1.png', '457 Main Street, ATL', 'Volvo', 'Black', 'Recognition confidence level is 98%');
```

ISSN (online): 2581-3048
Volume 10, Issue 7, pp 64-87, July-2026
https://doi.org/10.47001/IRJIET/2026.107008

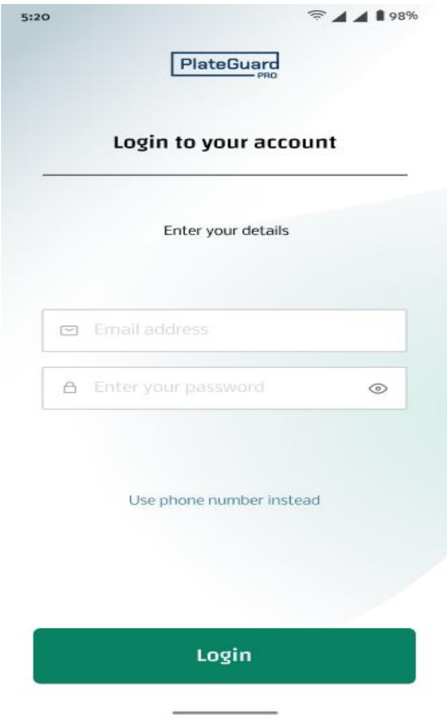
APPENDIX B

Sample Outputs

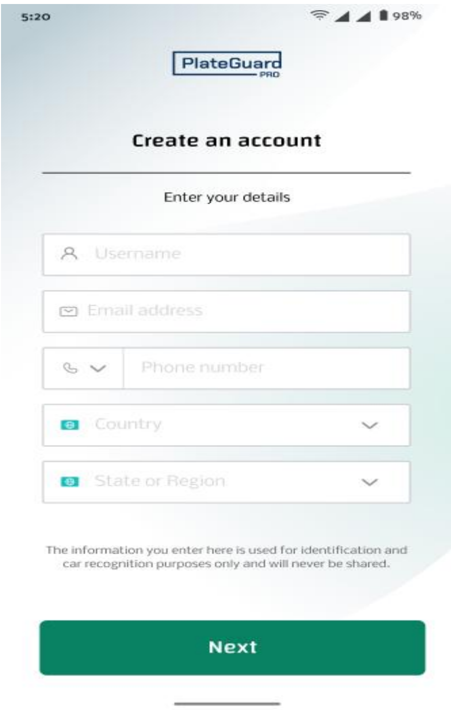
Feature Screens



Login Screen



Sign Up Screen



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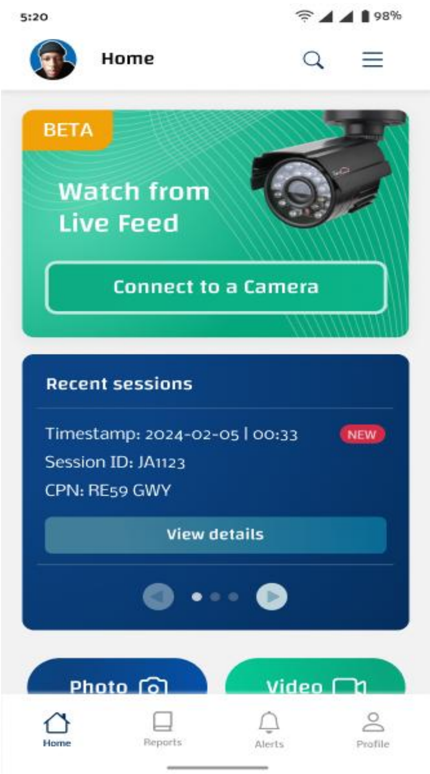
ISSN (online): 2581-3048

Volume 10, Issue 7, pp 64-87, July-2026

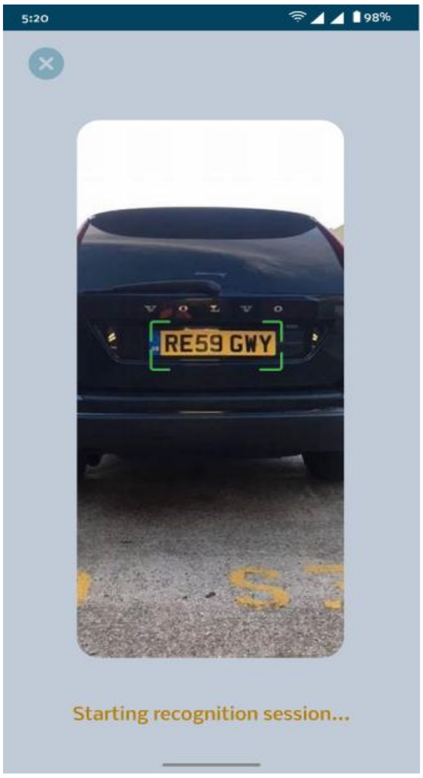
https://doi.org/10.47001/IRJIET/2026.107008

Home Screen



Capturing Car Plate Number

Starting Recognition Session



Running Recognition Session

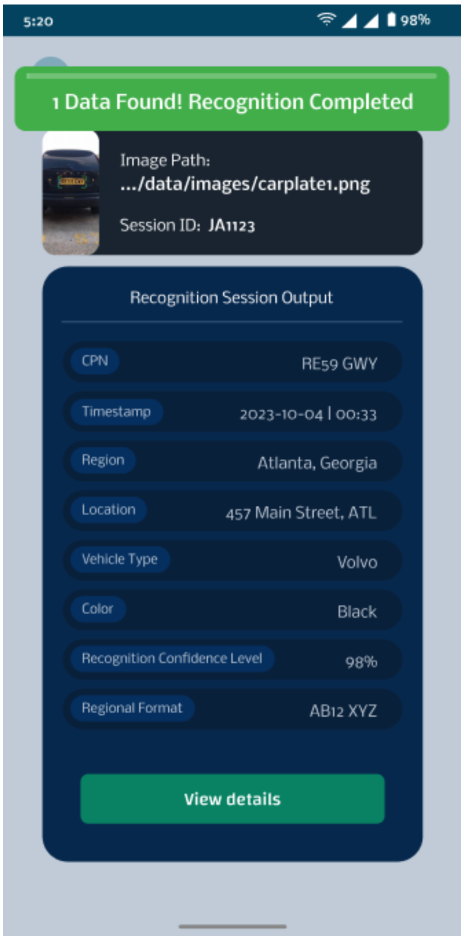
International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048

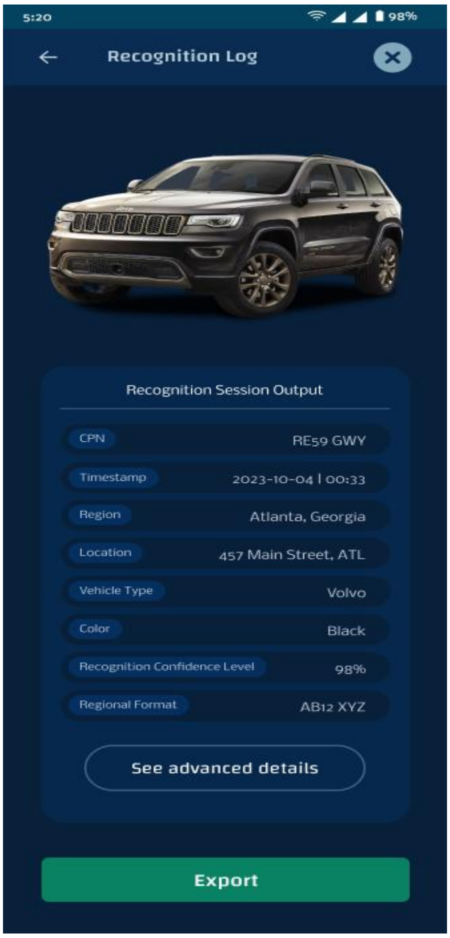
Volume 10, Issue 7, pp 64-87, July-2026

https://doi.org/10.47001/IRJIET/2026.107008

Completed Recognition – Found Data



Details of the Session



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