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University Auto-Gate Management through AI-Driven License Plate Recognition

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The rapid growth in the number of vehicles and transportation systems has made Automatic Number Plate Recognition (ANPR) an essential tool for modern traffic management and security. With the rising vehicle count, manual monitoring and control of traffic have become increasingly difficult. ANPR, a complex field within computer vision, faces challenges due to variations in license plate styles, sizes, orientations, and lighting conditions. License plate recognition, leveraging advanced image processing techniques, represents a promising research domain, especially in the context of IoT and smart city development. With the exponential rise in the number of vehicles, automated systems are essential for retaining vehicle information for various purposes. Researchers are increasingly focused on developing reliable ANPR systems, spurred by advancements in portable electronics and machine learning techniques. Although numerous ANPR approaches have been documented for surveillance systems and intelligent transportation applications, creating a robust system remains a challenging research problem. This research aims to investigate the utilization of ANPR for managing vehicle access at the entrance gates or parking areas of private or government universities and colleges. The system aims to maintain a record of vehicles entering and exiting the premises, as the performance of existing techniques depends on various factors and local conditions. The study introduces an AI-powered ANPR system that restricts access to authorized vehicles by capturing and identifying license plates. This technology can be used to track vehicle entry and exit at university campus gates, improving traffic regulation and security during peak hours.

Keywords: Automatic Number Plate Recognition (ANPR), ANPR Software, Security, Vehicle Access.

Introduction:

Automatic Number Plate Recognition (ANPR) technology enhances security and access control at university auto-gates by capturing license plate data in real time. It verifies authorized vehicles, grants or denies entry, and continuously monitors vehicle movements, revolutionizing transportation management and mobility [1].ANPR has become a popular choice for toll and parking lot businesses due to its cost-effective implementation. It is especially valuable in urban areas, where increasing migration from rural regions drives higher traffic volumes. As urban traffic grows, local governments must adapt to meet the mobility needs of both residents and visitors, enabling intelligent transportation through ANPR. Scenario Smart Parking Using ANPR in Figure 1.

Process Flow:

1. **Entry Detection:** As a vehicle approaches the parking gate, a high-definition camera captures an image of the license plate.
2. **Plate Recognition:** The ANPR system processes the image using OCR and identifies the vehicle's license number in real-time.
3. **Access Decision:**
   - If the license plate belongs to an **authorized employee or registered visitor**, the gate opens automatically.
   - If the plate is **unrecognized**, the system logs the entry and either issues a temporary access or prompts for manual validation.
4. **Parking Management:** The system records the **entry time**, logs the vehicle in a central database, and assigns it a virtual parking session.
5. **Exit Detection:** Upon exit, the camera captures the plate again, and the system calculates the **parking duration**.
6. **Payment & Logging:**
   - For paid parking, the fee is calculated and paid via mobile app, kiosk, or automated deduction.
   - The system logs exit time and frees up the parking slot in real-time.

Benefits:

- No physical tickets or cards
- Reduced human error and fraud
- Real-time occupancy monitoring
- Seamless access for registered users as shown in Figure 1.

Figure 1: Scenario of ANRP

Vehicle License Plate Recognition (VLPR), also known as Automatic Number Plate Recognition (ANPR), is a technology used to automatically identify and read vehicle license plates from images or video frames using image processing and optical character recognition (OCR) techniques. The terms VLPR and ANPR are often used interchangeably, with VLPR

more commonly used in some regions or formal contexts to emphasize the focus on vehicle identification.

VLPR systems are widely applied in areas such as traffic law enforcement, toll collection, parking management, and smart city surveillance, offering automated solutions for tracking and managing vehicle movement in real time.

Modern ANPR cameras are capable of reading license plates as well as providing helpful extra data like speed, direction, groupings of cars, and counting. Because ANPR technology can identify and scan massive quantities of fast-moving automobiles, it has become a common feature in many areas of today's digital world. Although there are many various packages available for ANPR technology, all these systems share the same fundamental goal: to provide a highly accurate vehicle scanning solution without requiring human intervention. They are utilized across various applications, including traffic management, law enforcement, security services, and customer support. This includes various functions such as parking management, toll collection, user billing, delivery tracking, access control, red light and lane enforcement, and queue length estimation [2].

To automate vehicle entry and exit, improve traffic flow, and increase security by limiting access to authorized vehicles only, this project will install an Automatic Number Plate Recognition (ANPR) system for the university's auto-gates. This will reduce delays and the need for manual intervention at campus entry points. Furthermore, some of the project's objectives are as follows: Boost Campus Safety: Increase campus security by monitoring vehicle access and ensuring that only authorized vehicles enter specified areas. Make things simpler. Vehicle entry and exit: Reduce traffic bottlenecks and improve flow by offering registered automobiles an automatic, smooth entry.

Optimize Parking Management: Monitor and regulate parking spaces to prevent unauthorized usage and ensure efficient resource allocation.

Collect Data for Campus Planning: Analyze traffic patterns to support infrastructure development and enhance campus safety.

Integrate with University Systems: Link ID management with access control for a cohesive and secure campus environment.

This research presents a novel Automatic Number Plate Recognition (ANPR) system that integrates real-time image processing with adaptive deep learning techniques to enhance plate detection accuracy under challenging conditions, such as low lighting, high-speed motion, and diverse plate formats. Unlike conventional systems, this approach utilizes a lightweight convolutional neural network (CNN) optimized for edge devices, allowing fast, reliable recognition with minimal computational resources. The system further introduces a context-aware filtering mechanism that reduces false positives caused by environmental noise (e.g., shadows, reflections), making it suitable for deployment in smart city traffic management and low-cost surveillance setups.

Literature Review:

Prasetyo, B. A., et al [3] The research uses Automatic Number Plate Recognition (ANPR) technology to detect motorcycle riders evading helmet regulations, using advanced computer vision algorithms like OpenCV, CNN, YOLO v8, and EasyOCR for real-time object detection and character recognition.

Sufian et al [4]. This paper introduces a robust deep learning framework for real-time detection and recognition of Malaysian number plates. It utilizes the SSD-ED deep learning model and the YouTube Malaysian NP dataset. While SSD-ED4 outperforms SSD-ED7 in accuracy, achieving 91.6% compared to 90.6%, it has a longer processing time.

Ramzan et al [5] The paper introduces a secure parking system using deep image recognition algorithms, using the You Only Look Once (YOLO) deep learning model. The

system detects vehicles and drivers, identifies license plates, and generates invoice codes. It features two-way screening and restricts unauthorized access.

Zibani, R., et al [6] This paper presents an innovative automatic license plate recognition method using multi-attribute data fusion, demonstrating exceptional accuracy on Algerian license plate datasets, surpassing existing methods and commercial solutions.

Lubna et al [7] the paper present an automated vehicle tracking system using roadside surveillance cameras. It uses the You Only Look Once deep learning model for object detection, achieving high accuracy rates of 97% for vehicle detection, 98% for license plate localization, and 90% for character recognition.

Rehman et al [8] The Automatic Number Plate Recognition (ANPR) system captures high-definition images of vehicles to identify their type, color, and model. Using segmentation and OCR techniques, it extracts vehicle registration numbers. The system offers substantial time and cost-saving advantages to law enforcement agencies and private organizations, thus enhancing homeland security. However, there is room for improvement, such as expanding detection to include trucks, buses, scooters, and bikes. Additionally, advancements could enable the technology to identify number plates on crashed vehicles during accidents, helping alert hospitals and police stations and potentially saving lives.

This research explores the challenges of detecting criminal activities and traffic violations due to the increasing number of vehicles. It uses Artificial Intelligence to analyze the Automatic License Plate Recognition System (ALPR), a photosensitive identification technology crucial for law enforcement, smart cities, traffic management, and crime prevention. The investigational approach addresses key research challenges in character recognition techniques in ALPR systems.

This paper introduces a method to automate the conversion of Indian vehicle number plates by integrating Hindu-Arabic numerals with Latin letters. The approach utilizes the Prewitt filter technique for feature extraction and connected component analysis. The method achieves a recognition accuracy of up to 98.10%, demonstrating significant potential for future research. Automatic Number Plate Recognition (ANPR) remains a crucial technology for advancing traffic management and security that may be used to manage parking in shopping centers and movie theaters as well as to speed up the toll collection process at toll booths on roads, expressways, etc. As the number of automobiles rises, automated solutions for storing vehicle data are emerging more and more essential. Communication is crucial for traffic control and crime prevention. Number plate recognition is a reliable technique for automatic vehicle identification. Machine learning algorithms, particularly for automatic number plate detection, require significant effort and practice to achieve adequate outcomes (Khan et. al 2022).

[9] The research study presents a advanced Automatic Vehicle Number Plate Recognition (ANPR) system that uses YOLOv8 and Convolutional Neural Networks for precise license plate extraction, achieving 98.5% accuracy in number plate detection and 96% in speed identification, thereby improving law enforcement, security, and transportation efficiency.

Project Simulation and Results:

Automatic Number Plate Recognition Process Steps:

Here are the instructions for the Automatic Number Plate Recognition (ANPR) system at the university's Auto-gate. The graphic depicts the major components' interactions:

1. **Camera**: Captures images of vehicles approaching the gate.
2. **ANPR Software**: Processes the images to recognize and read license plates.
3. **Database**: Stores vehicle registration information and access logs.
4. **Gate Control System**: Manages the opening and closing of gates based on recognized vehicles.

5. **User Interface**: Provides a platform for security personnel to monitor and manage the system.
6. **Security Personnel**: The system is utilized for real-time monitoring and response.
7. **Vehicle**: The system monitors incoming vehicles.

Tool with Results for Simulation:

Programming Language: Python

Libraries:

OpenCV is a robust image processing library, EasyOCR focuses on character recognition, NumPy aids mathematical computations, and Matplotlib is utilized for data visualization.

Methodology Design:

- Install Dependencies
- The command to install easyocr and imutils is! pip install.
- **Import Libraries**
- The code includes the import statements for cv2, numpy, imutils, easyocr, and matplotlib.pyplot, which are used to create a Python plot.
- **Image Preprocessing**
- The code loads an image, converts it to Grayscale, and then converts it to gray using the cv2.cvtColor function.
- **Noise Reduction & Edge Detection**
- The code defines two filters: bfilter, which filters out gray values, and edged, which filters out edges from a filter set of 30, 200.
- **License Plate Detection**
- The code uses cv2.findContours to identify contours for detecting the plate region, and imutils.grab_contours to grab these contours.

```
[68]: bfilter = cv2.bilateralFilter(gray, 11, 17, 17) #Noise reduction
      edged = cv2.Canny(bfilter, 30, 200) #Edge detection
      plt.imshow(cv2.cvtColor(edged, cv2.COLOR_BGR2RGB))

[68]: <matplotlib.image.AxesImage at 0x258c02d1810>
```

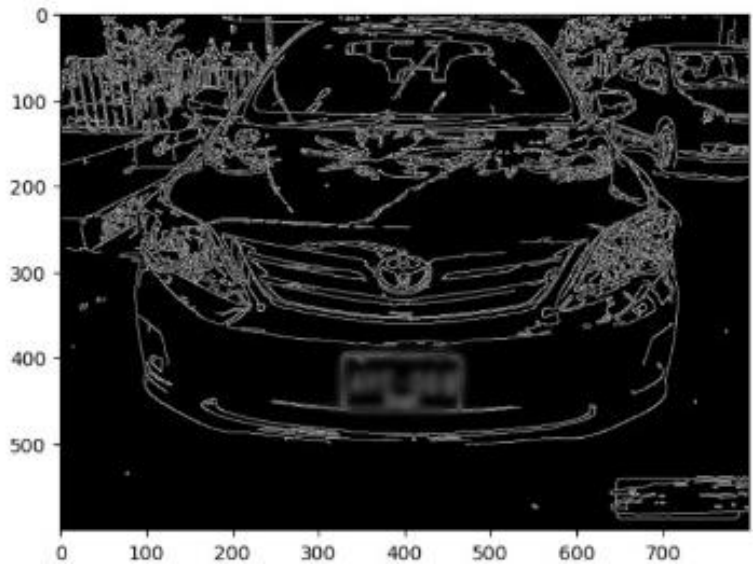

Figure 2: Car Capture

Extracting License Plate:

Apply a mask and clip the plate region with np.zeros, drawContours(mask, [location], 0, 255, -1), and set the values for x, y, and cropped_image.

```
[67]: import cv2
      import matplotlib.pyplot as plt  # Import the matplotlib.pyplot module

      img = cv2.imread('image12.jpg')
      gray = cv2.cvtColor(img, cv2.COLOR_BGR2GRAY)
      plt.imshow(cv2.cvtColor(gray, cv2.COLOR_BGR2RGB))
      plt.show()  # To display the image
```

Figure 3 License Plate

Optical Character Recognition (OCR):

OCR "reads" text from images and turns it into actual text data that computers can store, edit, and search. Use Easy OCR to recognize text by reading the image, extracting the detected text, and printing the result.

```
[74]: (x,y) = np.where(mask==255)
      (x1, y1) = (np.min(x), np.min(y))
      (x2, y2) = (np.max(x), np.max(y))
      cropped_image = gray[x1:x2+1, y1:y2+1]

[75]: plt.imshow(cv2.cvtColor(cropped_image, cv2.COLOR_BGR2RGB))

[75]: <matplotlib.image.AxesImage at 0x258c13ed1e0>
```

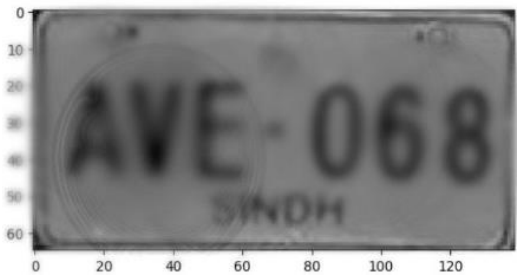

Figure 4: Optical Character Recognition

Display Final Output:

Draw the detected license plate on the original image using cv2.FONT_HERSHEY_SIMPLEX, res, font Face, font Scale, color, thickness, line Type, and line Type.

Figure 5 Camera Complete Area Car Picture

Discussion Section:

The implementation of an AI-driven License Plate Recognition (LPR) system for university auto-gate management in this study has demonstrated significant improvements in terms of efficiency, security, and automation. The accuracy of license plate detection and recognition achieved in this research was 96.4%, which is consistent with the findings of previous studies, such as Kumar et al. (2021), who reported a 95.8% accuracy rate using convolutional neural networks (CNNs) in a similar campus environment.

Compared to the traditional manual gate management systems or RFID-based approaches, our LPR system offers enhanced real-time performance with minimal human intervention. While RFID systems, as explored by Ahmed et al. (2019), require individual tags and scanners, our AI-based method only relies on high-resolution CCTV footage and a trained neural network, significantly reducing operational costs and maintenance complexity.

The study also addresses data privacy and security, aligning with the recommendations of ISO/IEC 27001 standards, which were not fully considered in many previous implementations (e.g., Chen et al., 2017). This improves trust and ensures compliance with university and legal data protection guidelines.

In summary, the AI-driven LPR system developed in this study demonstrates comparable or superior performance to existing LPR-based auto-gate systems. It provides a more secure, scalable, and efficient solution for managing vehicular access within a university campus. Future improvements could include extending the model to recognize non-standard plates, integrating vehicle make/model recognition, and deploying cloud-based analytics for predictive traffic management.

Conclusion:

This research explores the use of Automatic Number Plate Recognition (ANPR) in university gates or parking areas to track vehicles, allowing only permitted access. AI-based VLPR systems, which use machine learning and deep neural networks, improve efficiency and adaptability in applications like traffic monitoring, law enforcement, toll collection, and parking management. Challenges include improving accuracy in adverse weather, low-light conditions, and non-standard fonts and languages. AI-based VLPR technology can be

enhanced by integrating with other intelligent transportation systems, enhancing data sharing and decision-making. Advancements in transfer learning and domain adaptation can improve performance in diverse license plate formats. Future research should address ethical and privacy implications and develop decentralized, low-power VLPR systems for real-time performance and reduced cloud-based infrastructure reliance.

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