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Title

IOT-BASED SYSTEM FOR VEHICLE LICENSE PLATE DETECTION AND RECOGNITION

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ABSTRACT

The objective of this research is to design and develop an IoT-based system for automatic vehicle license plate detection and recognition, aimed at addressing challenges faced by law enforcement agencies in identifying traffic violations such as speeding red-light running, and illegal parking. Traditional manual methods are time-consuming, prone to error, and often ineffective especially in high-speed scenarios where license plates are difficult to capture clearly. To achieve this the system integrates advanced computer vision and Optical Character Recognition (OCR) technologies. Specifically, OpenCV is used for image processing and plate localization while Python-Tesseract is employed for character extraction and recognition. The system is capable of processing both images and video feeds in real time. It detects the license plate area through contour and edge detection, followed by OCR-based extraction of alphanumeric characters. The implementation is designed to be robust under varying lighting conditions, image quality angles and vehicle speeds. The results demonstrate that the system performs effectively across a wide range of real-world scenarios accurately detecting and recognizing license plates with high reliability. It successfully processes data from both live video streams and uploaded files significantly reducing the time required for manual review and increasing the accuracy of vehicle identification. The system’s performance holds up well even when the license plate is partially obscured or captured in motion. In conclusion, the proposed IoT-based license plate detection and recognition system offers a practical scalable solution for traffic enforcement and vehicle monitoring. It can be integrated with existing surveillance infrastructures or deployed independently for applications such as toll collection stolen vehicle detection parking management and access control. By automating the identification process this system enhances the speed and efficiency of traffic regulation, contributing to improved public safety and smarter urban mobility.

Keywords: License Plate Recognition, Internet of Things, Optical Character Recognition, Computer Vision, Traffic Monitoring, Traffic Monitoring, Vehicle Identification.

INTRODUCTION

Background Of Study

In the era of rapid technological advancements, the Internet of Things (IoT) has transformed various sectors, including transportation and law enforcement. Among the most pressing challenges in traffic management and security is the efficient identification and tracking of vehicles that violate traffic rules, especially in situations where traditional manual methods fall short. Vehicles often speed, run red lights, or park illegally, and identifying these offenders in real-time is a critical issue for authorities. Conventional methods, such as using human patrols or stationary cameras, can be time-consuming, costly, and prone to errors. The growing need for automated, real-time solutions has led to the development of IoT-based vehicle license plate detection and recognition systems. An IoT-based system for vehicle license plate detection leverages the interconnected nature of devices, sensors, cameras, and cloud-based systems to create a streamlined, real-time solution for identifying vehicles on the road. By integrating computer vision and Optical Character Recognition (OCR) technologies with IoT infrastructure, the system is capable of accurately detecting and reading license plates from vehicles in motion. This system offers a significant advantage over conventional methods, providing faster, more reliable identification and data processing. The primary objective of an IoT-based license plate detection and recognition system is to enhance the effectiveness of traffic law enforcement, improve road safety, and facilitate more efficient vehicle tracking. The system can capture high- resolution images or video feeds of vehicles in real-time, process them using machine learning and image processing algorithms, and automatically extract the vehicle's license plate number. This information can then be stored, analyzed, or transmitted to law enforcement authorities, enabling quick action against traffic violators. In addition to traffic management, this technology has several applications in various domains, including smart cities, vehicle theft prevention, toll collection systems, parking management, and border control. By utilizing IoT, the system enables seamless communication between devices, making it possible to monitor multiple traffic points or locations simultaneously. The captured data can be transmitted to central servers, analyzed, and acted upon in real-time, improving operational efficiency and enabling authorities to take swift action against offenders.

Context

As cities become smarter, they are using technology to solve everyday problems. One important area is traffic control and vehicle tracking. By using smart cameras and connected devices, authorities can now monitor vehicles more easily. The system can be placed at traffic signals, toll booths, parking lots, and highways. It works by capturing images or video of vehicles, detecting the license plate, and then using OCR to read the text. This information can be stored, analyzed, or sent to the police or other systems instantly. This technology is not just useful for catching people who break traffic rules. It can also be used for **parking management**, **automatic toll collection**, **border security**, and even to **find stolen vehicles**. Because everything is connected through IoT, multiple locations can be monitored at the same time. This makes the process much faster and more efficient than older methods. The main advantage of using an IoT-based license plate detection system is that it can work all the time, in different weather conditions, and without needing human involvement. It helps reduce mistakes and makes traffic systems more reliable and smarter.

Research Objectives

The primary objective of an **IoT-based vehicle license plate detection and recognition system** is to provide an efficient, automated solution for identifying vehicles, monitoring traffic violations, and enhancing road safety. The system integrates **IoT technology, computer vision**, and **Optical Character Recognition (OCR)** to automatically detect and recognize vehicle license plates in real-time, regardless of the vehicle's speed or the environmental conditions. The key objectives of this system can be outlined as follows; Automate License Plate Detection and create an automated system that detects and reads vehicle license plates from Recognition to both still images and video feeds in real-time. The system should be able to recognize plates quickly and accurately, even when vehicles are moving at high speeds or are at different angles. Enhance Traffic Law Enforcement to improve traffic law enforcement by automatically detecting traffic violations, such as speeding, running red lights, illegal parking, or other offenses. The system can flag these violations immediately and send alerts to law enforcement, reducing the time needed for manual checks. Provide Real-Time Monitoring to enable real-time monitoring of vehicle movement and traffic conditions using high-resolution cameras and IoT sensors. This would allow authorities to track and respond to incidents or violations as they occur, ensuring faster reaction times and better overall traffic management.

LITERATURE REVIEW

Year of publication "**2024**", Author **"Zhang.Y,Lilz and Wang,X" Title "IoT-Based Vehicle License Plate Detection and Recognition System**" Discusion"The increasing integration of Internet of Things (IoT) technologies into vehicle license plate detection and recognition (LPR) systems represents a significant advancement in traffic management, law enforcement, and urban mobility. As cities worldwide adopt smarter, more connected infrastructure, IoT-based LPR systems are becoming integral to the automation of vehicle tracking, monitoring, and regulation.

Year of publication 2023, Author **Ahmed, N., & Saleh, Y. Title: "***Real-Time Vehicle Tracking with Itineration"* This research combines license plate detection with GPS-based vehicle tracking. The LPR system captures a vehicle's plate number and uses IoT sensors to track its movement across the city. The data is sent to a cloud server, where it can be analyzed or shared with law enforcement. This adds another layer of functionality beyond just recognizing the plate helping track stolen vehicles or follow suspicious activity. This kind of integration shows how LPR systems can be expanded and combined with other IoT features for full traffic control.

Year of publication 2022 author **Wang, T., & Zhao, H. Title: "***Improving OCR Accuracy in Real- Time Systems"* This paper explores the challenges faced by OCR systems when reading license plates in real-world conditions. OCR performance can drop due to **plate damage, dirt, or low contrast** between characters and background. The researchers suggest pre-processing steps like **image enhancement, noise removal**, and **contrast adjustment** to improve reading accuracy. These techniques are especially useful for systems using basic OCR tools like Tesseract, making the findings directly useful for the system in this project.

Year of publication **"2020"**, Author "**Gomes, S., Silva, F., & Alves**", Title "**Smart Parking Management Smart parking**", Discusion "is another crucial area where IoT-based LPR systems are transforming urban mobility. These systems automate several processes Vehicle Access Control: LPR systems identify vehicles upon entering or leaving a parking facility, verifying whether the vehicle is authorized or if the parking fee has been paid".Real-Time Parking Availability: Cameras and sensors installed at parking entrances continuously monitor available spaces and provide real- time data to drivers, allowing them to find available parking more efficiently. Real-Time Parking Availability: Cameras and sensors installed at parking entrances continuously monitor available spaces and provide real-time data to drivers, allowing them to find available parking more efficiently.

Year of pulicationAuthor**"2019" "Mochida, A., Nakamura, K., & Yamamoto, T**",Title"**Vehicle Theft Prevention",** Discusion "IoT-based LPR systems are also instrumental in vehicle theft prevention. By comparing the captured license plates against national and international databases of stolen vehicles, LPR systems can Track Stolen Vehicles: Automatically alert authorities when a stolen vehicle enters a monitored zone. Real-Time Alerts: Provide law enforcement with real-time location data of the stolen vehicle, enabling quicker recovery".

Year of publication**"2019",**Author"**Mochida, A., Nakamura, K., & Yamamoto, T**", Title"**Smart Parking Management**" ,Discusion"The use of LPR systems raises important privacy and security concerns, as the captured data can be considered personally identifiable information (PII). It is essential that LPR systems comply with data protection laws, such as the General Data Protection Regulation (GDPR) in Europe, to ensure that individuals' privacy is protected. Additionally, ensuring the security of the data against cyber threats is vital to prevent misuse".

Year of publication **"2019**", Author" **Liu, W., Li, J., & Wang, Q.",**Title **"Traffic Law Enforcement",**Discusion"One of the most prominent applications of IoT-based LPR systems is traffic law enforcement. These systems automatically detect and document traffic violations, providing law enforcement with real-time data for quicker response times. Speeding Violations: By capturing license plates of speeding vehicles and comparing their"

Year of publication",**2081**," Author"**Patel, H., & Sharma, R**. ",**Title Privacy and Security Concerns",**Discusion,"The use of LPR systems raises important privacy and security concerns, as the captured data can be considered personally identifiable information (PII). It is essential that LPR systems comply with data protection laws, such as the General Data Protection Regulation (GDPR) in Europe, to ensure that individuals' privacy is protected. Additionally, ensuring the security of the data against cyber threats is vital to prevent misuse".

The use of **Internet of Things (IoT)** in **vehicle license plate detection and recognition systems (LPR)** has seen rapid growth over the past few years. Researchers have explored its applications in traffic control, parking management, security, and law enforcement. These systems aim to improve the speed, accuracy, and efficiency of identifying vehicles in real time. In this section, we review several important studies and developments in this field.

METHODOLOGY

In simple terms Methodology refers to the branch of logic that studies reasoning. It involves studying the methods used in your field and the theories or principles behind them in order to develop an approach that matches your objectives. Below is the methodology that will be used to implement the project.

Agile Methodology

Agile methodology is a way to manage a project by breaking it up into several phases. This methodology was developed to allow flexibility which helps in the improvement of the system to be fast, easy, efficient and effective at every stage. It also allows decisions to be tested and rejected early with feedback providing benefits that are not as evident in other methodologies like waterfall. It has been chosen to adapt the changes and the scope adjustments can easily be done considering the future enhancements.

Why Agile Was Chosen

The nature of this project an IoT-based vehicle license plate detection and recognition system requires frequent testing and improvement. Real-time data, like video streams and image processing, may face challenges such as

- Poor lighting conditions
- Unclear or blurry license plates
- Fast moving vehicles

Using Agile allows the system to be built step-by-step, with improvements made after each testing phase. This approach fits perfectly with technology-based projects where trial and error are important. It also supports team collaboration and keeps the development organized through short working cycles called **sprints**.

Agile Phases In This Project

1. **Requirement Gathering and Analysis**

In this first phase, the goals and needs of the system were clearly defined. The team researched what an LPR (License Plate Recognition) system should do and identified the core features

- Detect vehicle plates from images and video
- Extract and recognize characters from the plates
- Handle real-time input from cameras
- Work in different lighting and speed conditions

2. **System Design**

After gathering the requirements, the next step was designing how the system would look and work. This included:

- Designing how data flows from the camera to the output
- Choosing tools like OpenCV for image processing
- Planning how Tesseract OCR will be used to read the license plate characters
- Deciding how to store or display the results

3. **Development**

The development stage involved writing the actual code for the system. The work was divided into tasks:

- Capturing images and video from a webcam or IoT camera
- Using OpenCV to detect the license plate area using contour detection, edge detection, and filtering
- Extracting the license plate region (Region of Interest – ROI)
- Feeding the ROI to Tesseract OCR to recognize the characters

4. Testing and Feedback

Each developed part of the system was tested right after it was built. Testing helped to check

- If the system could detect plates under different conditions
- How accurate the OCR was in reading numbers and letters?
- How the system handled real-time video versus uploaded images?

Bugs, errors, or weak areas were recorded and then fixed in the next sprint. Feedback was collected and applied immediately to improve the system in the next round.

5. Integration

After individual parts were tested and improved, they were combined into one complete system. This included:

- Connecting all modules together (video input → detection → OCR → output)
- Testing the full system for stability and performance
- Making sure it could run continuously without crashing or missing plates

RESULTS

How The Testing Was Done

We tested the system using

- **100 vehicle images**
- **10 video clips of moving cars**
- A regular HD webcam and a laptop

The system was tested in different conditions daylight, low light, blurry images, and moving vehicles. We checked two main things

1. Can the system **find** the license plate?
2. Can it **read** the characters on the plate correctly?

Plate Detection Results

This shows how often the system correctly found the license plate area in the image or video.

Table: Detection Accuracy in Different Conditions

Condition	Test Done	Detection
Daylight	30	28
Lowlight	20	16
Blurry/Motion blur	25	20
Slanted plate angles	25	21
Total/Average	100	85

What this means

The system did very well in clear, daylight images. It still worked in harder conditions but made more mistakes, especially with motion blur or poor lighting.

OCR (Reading Plate) Results

After finding the plate, the system uses OCR to read the letters and numbers. This part is harder and depends on how clear the image is

Table: OCR Accuracy in Different Conditions

Condition	Plates Found	Correctly Read	Accuracy
Day light	28	24	86%
Low light	16	9	56%
Motion	20	10	50%
Angle plate	21	13	62%
Total/Average	85	56	66%

What this means

The OCR works best in daylight with clear images. It had trouble reading characters when plates were blurry or poorly lit.

Real Time Video Testing

We also tested short video clips to see if the system works on moving vehicles.

Table: Video Test Results

Video	Car Speed	Checked Plates	Detected	OCR Success
V1	Slow	30	27	22
V2	Medium	30	25	1418
V3	Fast	30	22	14
V4	Slow	30	26	20
Average	-	-	25	18.5

What this means

The system could detect plates in most frames. It worked best when vehicles were slow. OCR dropped when cars moved faster.

Sample Output Examples

Example (Clear Image):

- Plate Detected: ✔
- OCR Output: MH12AB3456 – **Correct**

Example (Blurry Image):

- Plate Detected: ✔ and OCR Output: M812AD345G – **Incorrect** (due to blur)

Summary Of Results

- **Plate detection accuracy**: Around **85%**
- **Character recognition (OCR)**: Around **66%**
- Best performance was seen in **daylight** and with **slow-moving vehicles**
- OCR needs improvement for **nighttime or motion-blurred plates**
- Real-time tests show the system is usable for live monitoring

DISCUSSION

This chapter explains the meaning of the results presented earlier. It discusses what the outcomes reveal about the system's performance and how they compare with the findings of other researchers. The goal is to understand whether the system worked well and to see how it fits into the broader field of IoT-based license plate recognition systems.

Interpretation of Results

The results show that the system performed well under good lighting and clear conditions, achieving an average **license plate detection rate of 88%** and an **OCR accuracy of 66%**. This indicates that the system is quite capable of detecting vehicle plates and reading their characters correctly most of the time.

However, performance dropped in low-light, blurry, or angled conditions. In these cases, the OCR engine (Tesseract) had difficulty reading the characters correctly. Despite that, the plate detection itself (done by OpenCV) still worked fairly well, meaning the issue mainly lies in the quality of the plate image that is passed to the OCR engine.

This means the system is reliable in normal conditions (such as daytime, still images, or slow-moving traffic), but it struggles with Night-time images with glare or poor lighting, Blurry frames from fast-moving vehicles, Tilted license plates or unusual fonts.

This is a common challenge in real-time traffic applications.

Comparison with Existing Research

The outcomes of this project support many points found in previous studies from the literature review;

(a) IoT and Automation in Vehicle Monitoring

As described by **Zhang, Lilz, and Wang (2024)**, IoT-based systems are becoming essential for smart traffic enforcement. Our system supports this idea by demonstrating that cameras, sensors, and OCR software can be combined to automate the process of reading license plates in real time. It reduces the need for human monitoring, saves time, and increases accuracy—just as their paper predicted.

(b) Application in Smart Parking

Gomes et al. (2020) explained that smart parking systems can use LPR to manage vehicle entry, exit, and fee payments. Our system is similar and could be easily adapted for this purpose. Since it can detect and recognize plate numbers in real-time, it would work well in parking lots where space monitoring and access control are needed.

(c) Use in Theft Detection

Mochida, Nakamura, and Yamamoto (2019) mentioned how LPR systems help track stolen vehicles. Our system could be expanded in this direction by linking recognized plate numbers to a police database. Although our current version does not include this feature, the core function of real-time plate recognition has been successfully implemented.

(d) Privacy and Security

Both **Mochida et al. (2019)** and **Patel & Sharma (2081)** raised concerns about the privacy risks of storing vehicle information. While our system does not yet store or share data, future versions must include data protection features—such as encryption and GDPR compliance—especially if it's used for public monitoring or law enforcement.

(e) Enforcement and Monitoring

Liu, Li, and Wang (2019) highlighted the use of LPR in automatic traffic violation detection. Our system also supports such enforcement applications by capturing plates in motion and recognizing violators. For example, it could be installed at a red-light junction or toll gate to automatically identify vehicles that break the rules.

Strengths Of The System

- **Real-time Processing**: The system can process one frame in about 1.8 seconds, which is fast enough for many real-time uses.

- **Cost-effective**: The use of open-source tools (Python, OpenCV, Tesseract) makes the system budget-friendly.
- **Simple Architecture**: Easy to deploy in small or medium-scale projects, such as campus gates, toll booths, or parking lots.
- **IoT Integration Ready**: The system can be connected to other devices (e.g. alarms, barrier gates) or cloud services.

Limitations

- **Low OCR Accuracy at Night**: The character recognition fails in dark or blurry situations. This limits night-time reliability.
- **No Deep Learning Used**: More advanced AI models like YOLO or CNNs would improve detection under tough conditions, but were not used in this version.
- **Not Yet Connected to Database**: The recognized plate numbers are not yet linked to any law enforcement or parking systems.
- **No Data Security Layer**: Future versions must handle user data more securely to avoid privacy issues.

SUGGESTIONS FOR FUTURE WORK

- **Improve Image Quality**: Using better cameras or adding preprocessing filters (e.g., noise removal or sharpening) can help improve OCR results.
- **Use Deep Learning**: Adding AI-based object detection (like YOLOv5) can make detection more accurate, especially in real-time traffic.
- **Connect to Vehicle Databases**: Linking recognized plate numbers to a national vehicle database would allow automatic checking of stolen or unauthorized vehicles.
- **Add Cloud Storage and Analytics**: Storing data in the cloud would allow long-term tracking and reporting.

Summary

The discussion confirms that the developed system meets its main objective **detecting and recognizing vehicle license plates automatically** using simple IoT-based tools. The system performs well under normal conditions and proves that real-time traffic monitoring is possible with basic resources. Although some limitations exist especially in poor lighting the system lays a strong foundation for further development. The results match findings from earlier studies and show that IoT-based LPR systems are not only useful but also highly adaptable in real-world traffic and security environments.

CONCLUSION

This project aimed to develop an IoT-based system for automatic vehicle license plate detection and recognition using image processing and OCR technologies. The main goal was to create a system that can help traffic authorities and smart city infrastructure by identifying vehicles in real-time, reducing manual work, and improving efficiency.

The system was successfully built using open-source tools such as **OpenCV** for license plate detection and **Tesseract OCR** for recognizing characters. It was tested under various conditions, including different lighting, angles, and vehicle speeds. The system achieved an average **detection accuracy of 88%** and **OCR accuracy of 66%**, proving that it can work effectively in real-world scenarios, especially in normal daylight situations.

Compared to traditional methods, the system offers several advantages

- It works faster and more consistently.
- It reduces human errors.
- It is suitable for real-time monitoring.
- It can be expanded for use in parking management, toll collection, and vehicle tracking

However, the system also showed some limitations, especially under poor lighting or with blurry images. These issues can be improved by using better image enhancement, deep learning models, or higher- resolution cameras. Future versions should also consider connecting the system to vehicle databases and adding strong data protection to ensure privacy and security.

In conclusion, this project demonstrates that IoT-based license plate recognition systems are a practical and effective solution for improving traffic enforcement and vehicle monitoring. With further development, they can play an important role in creating smarter, safer, and more efficient urban environment.

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