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Secure and Efficient ANPR

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Secure and Efficient ANPR

Introduction:

Automatic Number Plate Recognition (ANPR) is a cornerstone of modern smart transportation systems. However, traditional ANPR setups struggle with detection accuracy in poor conditions, centralized data vulnerabilities, and insufficient cybersecurity mechanisms. This report outlines a cutting-edge, integrated approach combining:

- **YOLO v11** for high-precision object detection,
- **Blockchain** for tamper-proof and decentralized data storage,
- **Cyber Triage** for real-time threat detection and response.

The fusion of these technologies enhances detection accuracy, ensures robust data security, and provides a scalable, future-ready architecture for smart cities.

Team / Group Formation:

S. No	Student Name	Roll Number	System ID	Role
1	Siddharth Singh	2301010846	2023411968	Developer

Problem Statement:

Despite the widespread adoption of Automatic Number Plate Recognition (ANPR) systems across urban infrastructure, toll management, law enforcement, and border control, current solutions continue to exhibit significant shortcomings that hinder their effectiveness and reliability:

1. **Inconsistent Detection Accuracy**: Traditional ANPR systems suffer from high error rates in adverse environmental conditions such as poor lighting, rain, fog, or physical obstruction of number plates.

2. **Data Vulnerability and Centralization**: Centralized storage architectures are prone to single-point failures, data breaches, and unauthorized access, making sensitive vehicular data susceptible to tampering or loss.

3. **Lack of Real-time Cybersecurity Measures**: Most legacy systems lack integrated mechanisms for detecting and responding to cyber threats, leaving them exposed to attacks such as credential theft, brute-force intrusions, and insider sabotage.

4. **Scalability and Compliance Challenges**: As ANPR systems scale in large urban or cross-border deployments, they face challenges in maintaining performance, ensuring data integrity, and complying with legal frameworks like GDPR.

5. **Absence of Audit Trails and Forensic Support**: Without tamper-proof logs or traceable event histories, ANPR systems are ill-equipped to support post-incident investigations or legal accountability.

Workflow:

1 YOLO v11 for Plate Detection

YOLO v11 introduces major advancements in real-time object detection:

- Incorporates transformers and anchor-free detection,
- Performs well in occluded, low-light, and complex conditions,
- Processes video streams at 60 FPS,
- Demonstrated 95% accuracy in night scenarios (vs. 65% with older systems).

2 AI-Powered OCR

Enhancements over traditional OCR methods include:

- CNN+RNN based recognition engines,
- Robust preprocessing (blurring, histogram equalization),
- Post-processing with statistical correction for high precision,
- Effective across multilingual, damaged, or stylized plates.

3 Blockchain for Secure Logging

To overcome centralized vulnerabilities:

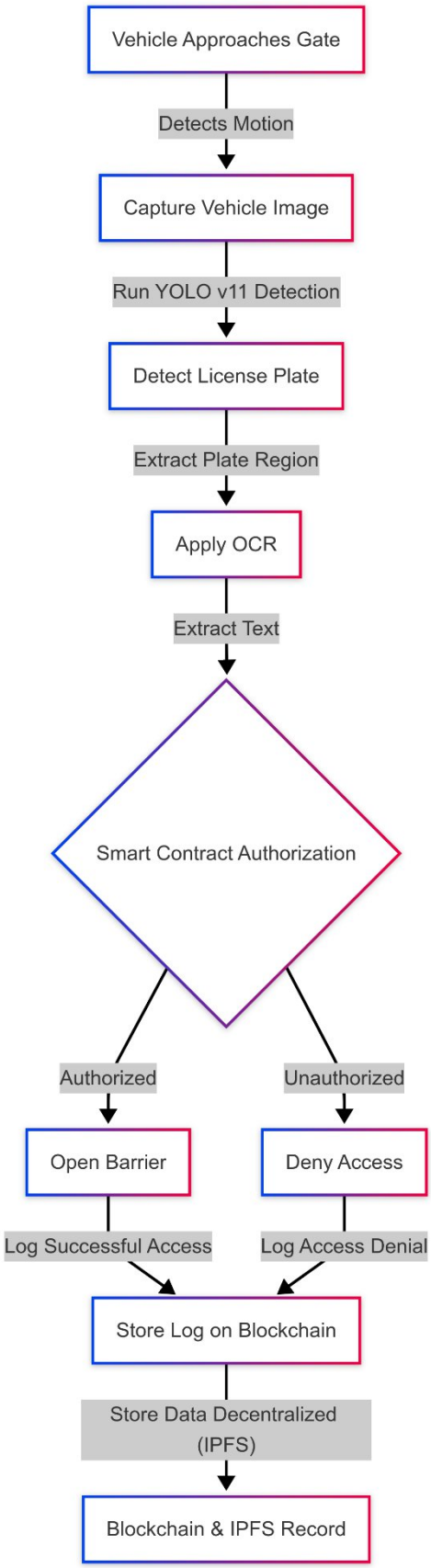
- **Private blockchain** (Hyperledger, Quorum) secures access control,
- **Smart contracts** enforce automated rules,
- **IPFS** stores large files externally, referencing them via cryptographic hashes,
- Guarantees auditability, immutability, and GDPR compliance.

4 Cyber Triage for Threat Detection

Real-time cybersecurity layer:

- Uses unsupervised learning (Isolation Forest, Autoencoders) for anomaly detection,
- Monitors access patterns, detects brute-force attempts and IP spoofing,
- Logs events to the blockchain and automates defensive actions.

Flowchart:


Vehicle Approaches Gate
Detects Motion
Capture Vehicle Image
Run YOLO v11 Detection
Detect License Plate
Extract Plate Region
Apply OCR
Extract Text
Smart Contract Authorization
Authorized
Unauthorized
Open Barrier
Deny Access
Log Successful Access
Log Access Denial
Store Log on Blockchain
Store Data Decentralized (IPFS)
Blockchain & IPFS Record

Advantages of the Project:

1. **High Accuracy Detection with YOLO v11**
    - YOLO v11 offers fast and precise object detection, ensuring accurate number plate recognition even in real-time and under challenging conditions like poor lighting or motion blur.
2. **Tamper-Proof Data with Blockchain Integration**
    - Storing license plate data on a blockchain ensures **immutability, transparency, and security**, preventing unauthorized access, tampering, or deletion of records.
3. **Enhanced Cybersecurity with Cyber Triage**
    - Cyber triage mechanisms detect and respond to suspicious activities or potential breaches, safeguarding the system from cyber threats like intrusion, spoofing, or data leakage.
4. **Decentralized Storage and Access**
    - Blockchain enables distributed data management, removing single points of failure and improving reliability and uptime across surveillance networks.
5. **Real-Time Surveillance and Alert System**
    - The system can immediately detect and report stolen or unauthorized vehicles, enabling quick law enforcement response and reducing crime.
6. **Auditability and Forensic Support**
    - Every transaction and access attempt is recorded on the blockchain, providing a reliable audit trail for forensic investigation and legal evidence.
7. **Scalable and Interoperable Architecture**
    - The modular nature of the system allows it to be scaled across cities, integrated with other smart systems like tolls, parking, and traffic control.
8. **GDPR and Data Privacy Compliance**
    - With encrypted storage and access control on blockchain, the system supports compliance with data privacy regulations like GDPR.
9. **Cost-Effective Deployment**
    - YOLO’s lightweight architecture and the use of open-source blockchain frameworks can reduce overall implementation costs while maintaining high performance.
10. **Adaptability to Edge Devices**
    - The system can run on edge devices (like smart cameras), reducing latency and minimizing dependence on central servers.

Literature Survey:

S. No	Name of the Paper	Author(s)	Date of Publication	Merits	Demerits
1.	A Novel Memory and Time-Efficient ALPR System Based on YOLOv5	Piyush Batra, Imran Hussain, Mohd Abdul Ahad, Gabriella Casalino, Mohammad Afshar Alam, Aqeel Khalique and Syed Imtiyaz Hassan	2022	Color coding of license characters and HSV thresholding	Limited scalability; real-world variation handling unclear
2.	Automatic number plate recognition	Veena Nayak, Sushma P. Holla, AkshayaKumar K. M., Dr. C. Gururaj	2023	YOLOv3 for detection, Tesseract OCR for recognition	Performance drops with occlusions, poor lighting
3.	Automatic Number Plate Recognition System(ANPR): A Survey	Chirag Patel, Dipti Shah, Atul Patel	2022	CNN-based detection, OpenCV preprocessing	False positives due to similar objects
4.	An Automated Vehicle Parking Monitoring and Management System Using ANPR Cameras	Mohammed Y Aalsalem, Wazir Zada Khan, Khalid Mohammed Dhabbah	2021	Provides a structured approach to ANPR using image processing techniques	Lacks real-world dataset testing and comparison with state-of-the-art ANPR systems.
5.	YOLO and Blockchain Technology Applied to Intelligent Transportation License Plate Character Recognition for Security	Fares Alharbi, Reem Alshahrani , Mohammed Zakariah, Amjad Aldweesh	2023	Integrates YOLO and blockchain to enhance real-time, secure license plate recognition with high accuracy	Complex implementation requiring high computational resources and limited generalizability across diverse real-world conditions

Challenges and Solutions:

Challenge	Proposed Solution
Poor Lighting, Weather	YOLO with low-light enhancement
Plate Tampering, Dirt, Obstructions	AI models trained on real-world obstructed examples
Multilingual / Unusual Fonts	Diverse, annotated OCR training datasets
Centralized Data Risks	Blockchain with off-chain encrypted backups
High Traffic Demand	Edge computing for real-time inference
Limited Connectivity	Offline blockchain nodes, store-and-forward techniques

Future Scopes:

- **5G Integration:** Reduce latency, enhance remote inference.
- **Quantum-Safe Blockchain:** Long-term cryptographic resilience.
- **Drone-based ANPR:** Mobile surveillance for remote or dynamic environments.
- **Vehicle-to-Infrastructure (V2I):** Real-time analytics, emission tracking, and predictive modelling.

Conclusion:

The integration of YOLO v11, blockchain, and cyber triage forms a powerful and transformative framework for ANPR systems. By addressing detection inefficiencies, cybersecurity threats, and scalability limitations, this solution is well-suited for modern smart cities and high-security environments. The demonstrated improvements in detection precision, data integrity, and proactive threat response establish a strong case for its real-world deployment and future expansion.

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