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AI-Driven Toll Plaza System with Number Plate Recognition using Optical Character Recognition

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ABSTRACT:

The implementation of an AI-driven Dynamic Toll Collection System that leverages Number Plate Recognition (NPR) and Optical Character Recognition (OCR) for automated toll management. The system aims to enhance toll segmentation and recognition ensure accurate identification. Upon successful verification, a One-Time Password (OTP) is generated and sent to the user's mobile for secure payment authentication.The system also supports secondary access authorization and real-time alerts for potential vehicle theft or fraud. By integrating automated gates, secure payment gateways, and a centralized database, this solution ensures seamless toll processing and improves overall system scalability, security, and user convenience. Implementation of this system could lead to significant advancements in intelligent transportation infrastructure and sustainable road network management.booth efficiency, reduce traffic congestion, and eliminate the need for manual or cash-based transactions. High-resolution cameras capture vehicle license plates, and OCR-based character.

Keywords: Number Plate Recognition (NPR),Optical Character Recognition (OCR),Automated Toll Booth, License Plate Detection, Secure Payment Gateway, OTP Verification, Vehicle Tracking, Traffic Management, Real-Time Processing.

1. Introduction

Toll collection at highways often leads to traffic congestion, delays, and inefficient management due to manual or semi-automated systems. To address these issues, this paper presents an AI-driven toll plaza system using Number Plate Recognition (NPR) and Optical Character Recognition (OCR) technology.

The system captures vehicle license plates using high-resolution cameras and processes the data through OCR to identify and verify vehicle information. Once verified, toll fees are automatically deducted via a secure One-Time Password (OTP) system, allowing for smooth, contactless toll passage.

This approach reduces traffic delays, enhances security, minimizes human intervention, and supports real-time vehicle tracking and alert mechanisms. The proposed solution is scalable, efficient, and eco-friendly, aiming to revolutionize modern toll management through automation and intelligent processing.

2. Literature Review

Early automated toll collection systems predominantly used RFID-based methods [8], which required physical tags and faced scalability issues. Advancements in Automatic Number Plate Recognition (ANPR) have utilized image processing and machine learning.[9] implemented Canny edge detection and template matching, though performance degraded under variable lighting. Integrating Optical Character Recognition (OCR), especially Tesseract with CNN preprocessing, improved accuracy to 92% on Indian datasets [3]. A hybrid CNN and morphological model for robustness in noisy environments [7].Real-time detection using YOLOv4 and ResNet-50 achieved high precision on moving vehicles in diverse lighting [6]. For vehicle classification, SVMs have been used to support dynamic tolling based on vehicle type and travel frequency [2]. An introduced OTP-based payment system integrated with UPI/FASTag APIs, enhancing security and reducing cash reliance[1].Security enhancements include tamper detection using Levenshtein distance and anomaly detection via ML classifiers [10], with blockchain gaining interest for immutable logging [5]. Lastly, edge-cloud toll architectures with AI dashboards enable real-time analytics, predictive maintenance, and congestion monitoring [4].

3. Existing System

Current toll collection systems incorporate a mix of traditional and semi-automated technologies to facilitate toll fee transactions and vehicle flow management. Conventional toll booths rely heavily on manual toll collection, where human operators interact with drivers to collect payments. This approach often leads to traffic congestion and delays, particularly during peak hours [1].

To address these inefficiencies, Electronic Toll Collection (ETC) systems have been implemented using Radio Frequency Identification (RFID) and transponder-based technologies. These systems enable automatic toll deduction as vehicles pass through designated lanes, significantly improving transaction speed and reducing queue times [8]. However, RFID-based ETC systems come with challenges, such as high initial infrastructure costs, vulnerability to environmental interference (e.g., rain), and occasional failures in tag recognition [8].

Some systems continue to use token-based or ticket-based mechanisms, supported by physical barriers and video surveillance for enforcement and monitoring. Although functional, these systems lack intelligent processing capabilities and real-time adaptability, limiting their scalability.

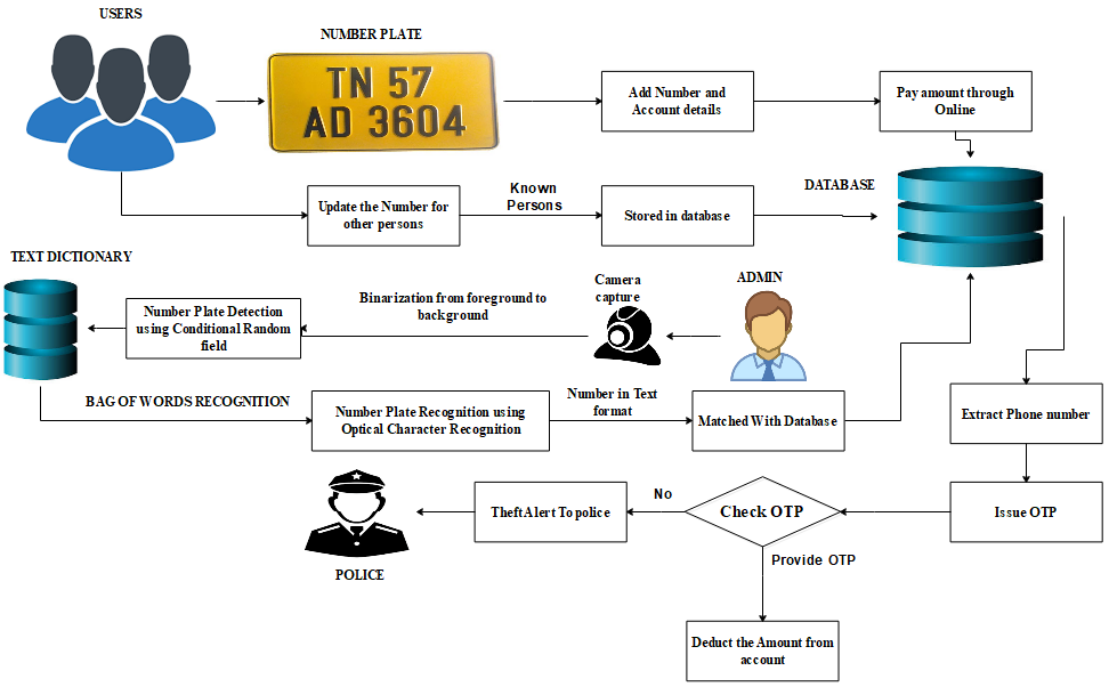
4. Proposed Systems

The proposed system leverages Automatic Number Plate Recognition (ANPR) to automate toll collection and vehicle verification. As a vehicle approaches the toll booth, a webcam captures an image of its license plate, which is processed to extract the unique license number using image-to-text conversion techniques. The system, connected via a PC interface, matches the license number with a database to verify the user.

Vehicle details including date, time, and ID are stored in an access database, and if the vehicle is valid, the toll amount is deducted via an online transaction. The user receives an SMS notification containing transaction details through web services. The system also stores images and text data, with potential for driver photo capture if configured. Region-specific license plate formats are supported for better recognition accuracy. This ANPR-based solution reduces human intervention, enhances efficiency, identifies stolen vehicles in real time, and enables better traffic and revenue data management.

Advantages

- Automates toll collection, reducing time and human effort.
- Ensures accurate and real-time vehicle verification.
- Identifies stolen vehicles without manual checks.
- Sends instant SMS notifications to users.
- Stores vehicle data for monitoring and analysis.
- Supports region-specific license plate formats.
- Improves detection range and system scalability.



5. Methodology

5.1 Image Capture and Preprocessing:

High-definition cameras are deployed at toll booths to continuously capture images of incoming vehicles. These images undergo preprocessing steps such as grayscale conversion, noise reduction using Gaussian filters, and edge detection (e.g., using the Canny algorithm) to isolate the number plate region from the vehicle.

5.2 Number Plate Detection and Segmentation:

After preprocessing, contour detection algorithms are used to locate the rectangular region of the number plate. This region is segmented to extract individual characters using morphological operations like dilation and erosion.

5.3 Character Recognition Using OCR:

Each segmented character is passed through a trained Optical Character Recognition (OCR) engine (e.g., Tesseract or a CNN-based model), which converts the visual characters into text data. This recognized text is matched with the toll database for identity verification.

5.4 User Authentication and Payment Processing:

Once the license plate is recognized, the system queries a centralized database to verify the vehicle's registration status and check for a linked toll account. A One-Time Password (OTP), generated using a secure SHA-256 seeded random generator, is sent via SMS to the registered mobile number using services like the Twilio API. Upon successful OTP verification, the toll payment is processed through integrated payment gateways such as UPI, FASTag, or mobile wallet APIs, and the barrier gate is automatically opened. In emergency scenarios, secondary users with pre-approved contact numbers can also be authenticated to facilitate transaction authorization.

5.5 Security and Alert Mechanisms:

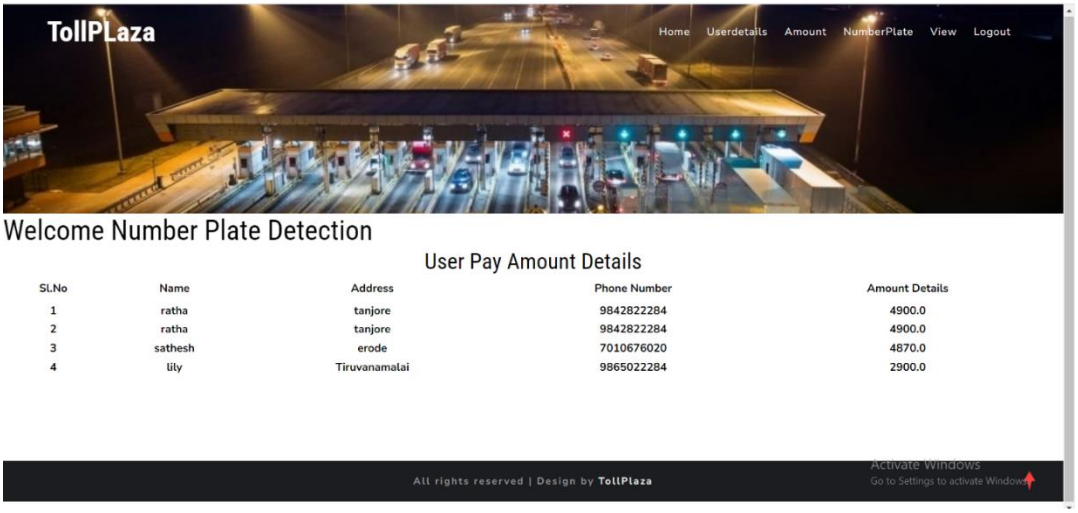
The system ensures secure operations by detecting OTP delays, mismatches, and number plate tampering. Alerts are sent to toll authorities or law enforcement in real-time. Tamper detection is performed using Levenshtein or Hamming distance, while anomaly detection monitors repeated OTP failures and irregular behavior. All events are logged in an encrypted cloud or blockchain database for audit and analysis.

5.6 System Integration and Real-Time Monitoring:

A web-based dashboard enables real-time monitoring of transactions, vehicle flow, and alerts. Data is encrypted and backed up regularly. The system uses React.js/Angular for the frontend, Node.js/Django for the backend, and MongoDB/PostgreSQL for storage. Real-time analytics are provided via Prometheus and Grafana on AWS or Azure.

6. Results and Findings

The developed AI-Driven Toll Plaza System successfully integrates Automatic Number Plate Recognition (ANPR) with OTP verification to streamline toll collection. When a vehicle approaches the toll booth, its license plate is captured by a web camera, and the system converts the image into text using OCR. Once the license plate number is recognized, the system retrieves the corresponding user details from the database. The user receives an OTP (One-Time Password) on their registered mobile number, which must be entered to proceed. Upon successful OTP entry, the system displays the toll transaction details, including the user's name, address, phone number, and the amount paid. The output clearly shows accurate matching of vehicle data and payment information for multiple users, ensuring transparency and authentication.



7. Conclusions & Future Enhancements

The AI-driven toll collection system utilizing Number Plate Recognition (NPR) and Optical Character Recognition (OCR) offers a transformative solution to modern toll management challenges. By automating number plate detection and integrating OTP-based secure payments, the system reduces the dependency on manual toll operations, minimizes human error, and ensures faster, contactless, and more secure transactions. The integration of high-resolution cameras and intelligent verification processes enables real-time identification of vehicles, enhancing both operational efficiency and user experience. Additionally, the system's ability to alert authorities in cases of suspected theft adds a critical layer of security. Looking forward, the system can be enhanced by incorporating cloud-based data analytics for centralized toll monitoring, using advanced AI models for better accuracy under varying weather and lighting conditions, and integrating mobile applications for real-time user notifications and toll history management. Future versions could support multi-lane simultaneous processing, blockchain for transaction transparency, and integration with national vehicular databases for law enforcement support. These enhancements would not only strengthen the system's robustness but also contribute significantly to smart transportation infrastructure and environmental sustainability.

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