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Development of Redlight Violation Detection System for Heterogeneous Traffic

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Abstract

This paper discusses the development and implementation of an Automated Red Light Violation Detection (RLVD) system designed to monitor traffic violations at intersections in Mumbai, specifically focusing on the Sakinaka intersection and major junctions. The system integrates advanced video analytics, secure data transmission, and on-site processing to detect violations such as running red lights. The study also covers the technical specifications, system feasibility, data collection procedures, and power calculations essential for system deployment. The findings suggest that the RLVD system can effectively reduce traffic violations, contributing to improved traffic safety.

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1. Introduction

Traffic violations at signalized intersections are a common issue in urban areas, leading to accidents, traffic congestion, and an overall decrease in road safety. The advent of automated traffic enforcement systems, such as Red Light Violation Detection (RLVD) systems, offers a solution to reduce violations and improve traffic law enforcement.

This study focuses on the development and implementation of an RLVD system at the Sakinaka intersection in Mumbai, which has been identified as a hotspot for red light violations. The primary objective is to design and deploy an automated system that detects and processes red light violations in real-time, providing evidence for law enforcement.

The RLVD system uses advanced video analytics, Artificial Intelligence (AI), and secure data transmission protocols to detect violations and automatically capture video evidence, ensuring that traffic law enforcement is more efficient and less reliant on manual intervention.

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2. System Overview

The RLVD system designed for Sakinaka aims to monitor and capture traffic violations at intersections by using high-resolution cameras (ANPR and overview cameras) and Infrared (IR) illuminators. The key features of the system include:

- **Video Capture and Image Analysis**: High-definition cameras (2MP resolution) capture videos and images at the intersection, with frame rates of 25-50 fps. The system is capable of storing and analyzing video and images before, during, and after the violation event.

- **Data Encryption and Integrity**: Each piece of evidence captured is watermarked and encrypted using AES (Advanced Encryption Standard) encryption, ensuring the integrity and authenticity of the evidence.
- **Automated Data Transfer**: The violation data is securely transmitted to a central server through FTP or GPRS-based wireless technology for further processing and archiving.
- **On-Site Processing**: Data processing is carried out at local processing units, ensuring that the system operates effectively even if the connection to the central server is temporarily lost. Local storage supports up to seven days of video and image data, with automatic overwriting.
- **Real-Time Violation Detection**: The system uses video analytics to detect red-light violations and logs data, which is then transmitted to the Traffic Control Center (TCC) for further analysis.

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3. Technical Specifications

The system requires several key components to function optimally. The following section outlines the technical specifications for the system's various hardware and software elements.

3.1 Video Analytics Engine

The Video Analytics Engine processes video data captured by the cameras to detect violations. The system uses machine learning algorithms to analyze traffic patterns, vehicle movements, and signal changes. The engine is capable of detecting red-light violations by analyzing vehicle behavior at the stop line and ensuring compliance with traffic signals.

3.2 Camera Specifications

The system is equipped with the following camera specifications:

- **ANPR Camera**: 2MP resolution with HD video output at 25/50 fps.
- **Overview Camera**: 2MP resolution with HD video output at 25/50 fps.
- **Infrared (IR) Illuminators**: Ensure clear video capture even in low-light conditions, operating with 850nm wavelength.

The cameras are designed for outdoor use and can operate in harsh weather conditions, meeting IP66 and IK10 standards for weatherproofing and vandal resistance.

3.3 Local Processing Unit (LPU)

Each installation is equipped with a local processing unit (LPU), which includes the following specifications:

- **Processor**: Intel Core i5
- **RAM**: 4GB
- **Hard Disk Drive (HDD)**: 2TB for storing video footage
- **Storage Capacity**: Local storage supports up to seven days of video data, with automatic overwriting capabilities.

The LPU ensures that even in case of network failure, the data is captured, stored, and processed locally.

3.4 Communication and Data Transmission

Data is transmitted from the local processing units to the central Traffic Control Center (TCC) using GPRS-based wireless technology (with 3G upgradeable to 4G capability) or wired connectivity. The communication between components is encrypted using AES to ensure data security and integrity. The violation data, including images and videos, is stored in a tamper-proof format.

3.5 Power Consumption

The system's power requirements are carefully calculated to ensure reliable operation. The power calculation for the Sakinaka intersection site indicates the following:

- **Camera Power Consumption**: 12.2W per camera
- **IR Illuminator Power Consumption**: 32W per unit
- **Server Power Consumption**: 350W per server

These calculations help determine the need for appropriate power backup systems (UPS) to ensure continuous operation.

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4. Data Collection and Field Survey

Before the system's implementation, a field survey was conducted to assess traffic volume and violation rates at the Sakinaka intersection. The data collected includes:

- **Traffic Volume**: Average vehicle count during peak and non-peak hours.
- **Violation Rate**: Percentage of vehicles running red lights during signal changes.

The data collected revealed that the violation rate at the Sakinaka intersection was alarmingly high, particularly during peak hours. This validated the need for an automated red-light violation detection system.

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5. Violation Detection and Processing Flow

The violation detection process follows a structured sequence to ensure accuracy and reliability. The stages in the violation detection process include:

- **Video Capture and Initial Processing**: High-definition cameras capture video and images at the intersection. The system processes the footage in real-time to identify vehicles violating the red-light signal.
- **Violation Detection and Data Logging**: If a violation is detected, the system logs the data, including the vehicle's license plate number, timestamp, and the violation event.
- **Checksum Generation and Data Encryption**: Each file generated by the system is assigned a checksum to ensure its integrity. The files are then encrypted using AES encryption before being transmitted to the central server.
- **Data Transmission to Central Server**: The violation data is transferred securely to the Traffic Control Center (TCC) using GPRS or wired connectivity.
- **Violation Processing at TCC**: Upon arrival at the TCC, the data is decompressed and processed to ensure accuracy. The violation details are then saved in the central database for further analysis.
- **Final Validation**: The violation processor performs a final validation of the data to confirm that the violation is valid and that the evidence files are intact.

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6. System Performance and Evaluation Initial results from the deployment of the RLVD system at the Sakinaka intersection show significant promise in reducing traffic violations. The violation rate at the Sakinaka chowk, especially during peak hours, was notably high, and the automated system has the potential to reduce violations by providing timely evidence for enforcement.

In addition, the system's performance is evaluated based on the following criteria:

- **Accuracy of Violation Detection**: The system achieves a high level of accuracy in detecting red-light violations, even in adverse weather conditions or low-light environments.
- **Data Integrity and Security**: The use of AES encryption and watermarking ensures that the evidence is tamper-proof and legally admissible.
- **System Reliability**: The local processing units and secure data transmission ensure that the system remains operational even in case of network interruptions.

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7. Conclusion

The automated Red Light Violation Detection (RLVD) system offers a promising solution to the growing issue of traffic violations at signalized intersections in Mumbai. By leveraging advanced video analytics, secure data transmission, and local processing capabilities, the system can effectively monitor traffic violations and contribute to improved road safety.

The study of the Sakinaka intersection highlights the need for such systems in urban areas, where traffic violations are prevalent. The implementation of the RLVD system is expected to reduce the number of red-light violations, improve law enforcement efficiency, and ultimately contribute to safer roads in Mumbai.

Future studies should focus on refining the system's algorithms for better detection accuracy and exploring the integration of additional sensors for more comprehensive traffic monitoring.

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8. References

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