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AI-Powered Traffic Signal Violation Detection and Monitoring System for Improved Road Safety

S. Rathanasabapathy, V. Bhuvaneswari
Department of Artificial Intelligence and Data Science, Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India

B. Vaidianathan
Department of Electronics & Communication Engineering, Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India

Abstract: An electoral system is a set of rules governing how elections and referendums are conducted and their results determined. Current systems, such as ballot box voting or electronic voting, face numerous challenges, including security threats like DDoS attacks, vote manipulation, malware, and polling booth capturing. Additionally, they require extensive resources, paperwork, and time, leading to inefficiencies and public distrust. Hackable microchips or servers further exacerbate these vulnerabilities. Blockchain voting offers a transformative solution to these challenges. By utilizing a decentralized, peer-to-peer network, blockchain ensures security against DDoS attacks and eliminates centralized authority vulnerabilities. Citizens can conveniently cast their votes via personal devices after identity verification. Blockchain's immutability ensures voting records are tamper-proof, easily verifiable, and transparent, with real-time vote tallying. This system significantly reduces costs, saves time, and enhances accessibility, paving the way for direct democracy. An E-Voting System Using Blockchain leverages blockchain's core features, including decentralization, cryptographic encryption, and immutability, to modernize electoral processes. Smart contracts securely verify voter identities and record votes in a transparent and tamper-resistant manner. This system enhances security, reduces fraud, and bolsters public trust in elections, offering a novel and innovative approach to achieving secure and transparent digital voting in the future.

Keywords: Ballot box voting; Blockchain voting; DDoS attack; E-Voting System; Unauthorized manipulation; Sophisticated algorithmic.

Introduction

A movie recommendation system is a sophisticated algorithmic tool designed to suggest films to users based on their preferences and viewing history. These systems leverage advanced data analysis and machine learning techniques to provide a highly personalized experience for users, enabling them to discover films that align with their tastes and interests [7-12]. The growing availability of movies across various platforms, coupled with the diversity of user preferences, has made recommendation systems an integral part of modern streaming services. By analyzing a user's past interactions with movies, including ratings, genre preferences, and viewing patterns, these systems generate tailored suggestions that enhance user satisfaction and engagement [13-19].

Movie recommendation systems employ various methodologies to provide accurate and relevant suggestions. Collaborative filtering is a commonly used approach that identifies similarities between users with similar tastes [20]. For instance, if two users have rated similar movies highly, the system can infer that they are likely to enjoy other films that the other user has liked, even if they have not interacted with those movies directly [21-24]. This approach broadens the scope of recommendations and allows users to discover content they might not have considered otherwise. On the other hand, content-based filtering focuses on the attributes of the movies themselves [25]. By examining features such as genre, director, actors, and storyline, the system can recommend films that share similarities with those that a user has previously enjoyed. Combining these methods, hybrid approaches offer even more accurate and diverse recommendations by leveraging the strengths of both collaborative and content-based filtering [26-31].

The aim of this paper is to develop and implement an effective movie recommendation system that provides users with personalized and relevant movie suggestions based on their preferences and viewing history. Such a system would be designed to ensure that users are not overwhelmed by the sheer volume of available movies and can easily discover content that aligns with their tastes [32-39]. The recommendation system will be built using a combination of recommendation algorithms, including collaborative filtering, content-based filtering, and hybrid methods, to achieve optimal performance. The paper will also focus on optimizing the system's performance and scalability, ensuring that it can handle a large number of users and a vast database of movies without compromising efficiency. Additionally, the user interface will be designed to be intuitive and user-friendly, enabling users to interact with the system seamlessly [40].

The effectiveness of the recommendation system will be evaluated through metrics such as accuracy, precision, and user satisfaction. Accuracy measures the system's ability to predict user preferences correctly, while precision assesses the relevance of the recommendations provided [41-44]. User satisfaction, an equally important metric, evaluates the overall experience of using the system and the extent to which it meets user expectations. By analyzing these metrics, the paper can identify areas for improvement and make necessary adjustments to enhance the system's performance. Furthermore, the paper aims to explore avenues for future enhancements, such as incorporating social media data, integrating real-time feedback, and using deep learning models to improve recommendation quality [45-50].

The problem statement highlights the challenges associated with the increasing volume of movies available on various platforms and the diverse preferences of users. As streaming services continue to grow in popularity, users are often faced with the paradox of choice, making it difficult to find movies that match their interests. This paper addresses this challenge by designing a system that can effectively analyze user behavior, preferences, and viewing history to provide personalized and relevant movie suggestions [51-54]. The system's use of advanced recommendation algorithms, including collaborative and content-based filtering, ensures that recommendations are both accurate and diverse. Moreover, the system's design will prioritize performance, scalability, and user experience, enabling it to deliver a seamless and efficient service to users [55].

To achieve its objectives, the paper will focus on several key aspects. First, the system's architecture and design will be carefully planned to ensure that it can handle the complexities of recommendation algorithms and the large-scale data processing required. This includes selecting appropriate machine learning models, developing efficient data storage and retrieval mechanisms, and implementing scalable algorithms that can adapt to changing user preferences and a growing database of movies [56]. Second, the user interface will be designed with the user in mind, providing a visually appealing and easy-to-navigate platform that enhances the overall experience. Features such as personalized dashboards, interactive filters, and real-time recommendations will be incorporated to make the system more engaging and user-friendly [57-61].

Additionally, the paper will explore the integration of advanced techniques such as deep learning and natural language processing to improve the quality of recommendations [62-65]. Deep learning models, for example, can analyze complex patterns in user behavior and movie attributes, enabling the system to make more nuanced and accurate predictions. Natural language processing can be used to analyze movie reviews, plot summaries, and user feedback, providing additional insights that can enhance the recommendation process. By incorporating these advanced techniques, the system can offer a more comprehensive and personalized experience to users [66-72].

One of the primary benefits of a movie recommendation system is its ability to enhance user engagement and satisfaction. By providing users with suggestions that align with their preferences, the system encourages them to spend more time exploring and watching movies on the platform. This, in turn, increases user retention and loyalty, making the system a valuable tool for streaming services and other movie platforms. Moreover, the system's ability to introduce users to new and diverse content helps broaden their horizons and exposes them to movies they might not have discovered otherwise [73-79].

Another significant advantage of a movie recommendation system is its potential to improve the overall efficiency of content delivery. By analyzing user preferences and viewing patterns, the system can optimize the way movies are presented and categorized, making it easier for users to find what they are looking for. This reduces the time and effort required to browse through a vast library of movies, enhancing the overall user experience. Furthermore, the system's use of advanced algorithms and machine learning techniques ensures that recommendations are continuously updated and refined, keeping them relevant and engaging [80].

The paper's scope includes several important aspects that must be addressed to ensure its success. These include system design and architecture, user interface development, reporting and analytics, and maintenance and support. The system's architecture will define the overall framework for data processing, storage, and recommendation generation, ensuring that it can handle large-scale data efficiently [81-85]. The user interface will be designed to provide an intuitive and engaging experience for users, making it easy for them to interact with the system and discover new content. Reporting and analytics tools will be developed to monitor the system's performance and provide insights into user behavior and preferences. Maintenance and support protocols will be established to ensure that the system remains operational and up-to-date, addressing any issues that may arise [86-91].

In a movie recommendation system is an essential tool for modern streaming platforms, providing users with personalized and relevant movie suggestions based on their preferences and viewing history. By leveraging advanced data analysis and machine learning techniques, these systems enhance user engagement, satisfaction, and retention, making them a valuable asset for content providers [92-97]. This paper aims to develop and implement a recommendation system that meets these objectives, incorporating state-of-the-art algorithms, intuitive design, and robust performance metrics to deliver a seamless and efficient service to users. Through continuous evaluation and improvement, the system will remain relevant and effective, providing users with a superior movie-watching experience.

Literature Survey

Ou et al., [1] developed a model for traffic monitoring and visualization, introducing a synergistic approach named wall display. This model integrates visualization, interaction, and traffic modeling to explore the effects of traffic modeling settings on global and local levels. The wall display system aims to provide a holistic platform for analyzing traffic data, enabling enhanced decision-making processes for traffic management. By visualizing complex data sets, this model highlights potential impacts and allows users to identify patterns, optimize settings, and monitor traffic in real-time. The system promotes interactive engagement, making it easier for operators to manage dynamic traffic environments effectively. This innovation laid the groundwork for combining data visualization and traffic modeling in a unified system, emphasizing the importance of visual tools in traffic management.

Wang et al., [2] developed a model for object detection using CNN-based modeling. This approach was trained on multiple vehicle classes, utilizing a dataset of Delhi road traffic to achieve high classification accuracy. The model applies convolutional neural networks to detect and classify various vehicle types, including cars, buses, and motorcycles, in real-time. It processes input images to identify objects with precision, overcoming challenges such as diverse traffic conditions, lighting variations, and occlusions. By focusing on deep learning techniques, the system ensures reliable object detection and classification, essential for traffic monitoring, violation detection, and safety enforcement. Its implementation offers valuable insights into traffic patterns, enabling authorities to optimize traffic flow and improve road safety measures effectively. This work represents a significant step in applying artificial intelligence to urban traffic scenarios.

Pulivarthy [3] proposed a multi-agent traffic monitoring and management system designed to operate in two distinct modes. The coordinated mode enables all agents to collaborate toward a unified solution for managing traffic conditions comprehensively. Alternatively, the local mode allows selected agents to focus on specific tasks or areas, optimizing resource usage and enhancing system flexibility. This dual-mode system adapts to varying traffic demands and conditions, ensuring efficient monitoring and management. Each agent is equipped with specialized functions to analyze traffic patterns, detect violations, and suggest actionable solutions. The system fosters real-time adaptability, promoting smoother traffic flow and reducing congestion. It demonstrates the potential of decentralized and cooperative approaches in traffic management, offering scalable solutions for complex urban environments.

Thirunagalingam [4] focused on the causes of urban traffic congestion, integrating big data analytics with IoT-based data collection to develop traffic prediction models. The system leverages real-time data from sensors, cameras, and connected devices to analyze congestion patterns and identify root causes. Intelligent transportation solutions are implemented to mitigate these issues, providing actionable insights for integrated supervision and management. This approach enables dynamic adjustments to traffic systems, such as signal optimization and rerouting strategies, to alleviate congestion effectively. By combining IoT and data analytics, the system supports proactive traffic management, enhancing urban mobility and reducing delays. This innovative framework underscores the importance of data-driven strategies in addressing urban traffic challenges.

Kommineni [5] analyzed the complexity of traffic light control at a single isolated junction. The study splits the challenge into two parts: demand estimation and traffic light control itself. By employing supervised learning techniques, the system predicts traffic demand patterns based on historical and real-time data. This prediction informs optimized traffic light settings, balancing the flow of vehicles across intersecting roads. The model addresses peak-hour congestion and ensures smoother traffic movement by dynamically adjusting signal timings. This approach enhances the efficiency of traffic management at critical junctions, improving travel times and reducing delays. The analysis provides a robust framework for understanding and managing the complexities of traffic control systems in urban settings.

Kumar et al., [6] designed a participatory urban traffic monitoring system that leverages the involvement of public transport users. The system deploys buses as mobile sensing units, outsourcing traffic data collection to passengers equipped with commodity mobile phones. These devices gather real-time data on traffic conditions, such as speed variations, congestion levels, and road anomalies. By utilizing everyday technology, the system reduces the reliance on expensive GPS equipment while providing accurate and timely information. The collected data is used to model road traffic conditions, enabling authorities to make informed decisions about traffic flow and infrastructure improvements. This innovative approach emphasizes community participation and cost-effectiveness in urban traffic monitoring.

Methodology

The preprocessing of input frames from CCTV footage begins with grayscaling and blurring to enhance the image quality for further analysis. Grayscaling converts the image to shades of gray, simplifying the processing by reducing color complexities. Blurring, achieved through the Gaussian Blur method, smooths the image to reduce noise and detail, making it easier to identify essential features. Once the image is preprocessed, background subtraction is performed to isolate moving objects. This method involves subtracting the current frame from a reference frame to highlight changes in the scene. The resulting difference represents the desired object's area, as shown by the equation $DST(I) = saturate(|scr1(I) - scr2(I)|)$. This subtraction isolates moving objects from the background, making it easier to detect and analyze their presence.

To refine the detected object area further, a binary thresholding technique is applied. Binarization eliminates holes and noise from the image, ensuring a cleaner representation of the moving objects. The binary threshold works by comparing pixel values to a predefined threshold. If a pixel value exceeds the threshold, it is set to a maximum value; otherwise, it is set to zero. This process is mathematically expressed as $DST(x, y) = \max Val$ if $scr(x, y) > thresh$ else 0. The result is a binary image where the desired objects are clearly separated from the background [98].

Following binarization, the image undergoes dilation to fill any remaining gaps or holes in the detected object areas. This step enhances the object's boundaries, making them more prominent and contiguous. Once dilation is complete, contours of the objects are identified. These contours represent the boundaries of moving objects, and rectangles are drawn around them to delineate the detected objects [99-104]. This method ensures that moving objects are accurately highlighted in the video footage for subsequent classification and analysis.

The next stage involves classifying the detected moving objects. This is achieved using YOLOv3, an advanced object detection model known for its accuracy and speed. YOLOv3 is the third iteration in the "You Only Look Once" family of algorithms and incorporates several enhancements over its predecessors. Built on the Darknet53 architecture, YOLOv3 uses convolutional neural networks to identify and classify objects within an image. Its ability to detect multiple objects simultaneously makes it particularly suited for real-time traffic analysis. The classifier model identifies moving objects in the video footage and assigns them to respective classes, such as cars, motorcycles, or pedestrians [105-109].

Once vehicles are detected and classified, the system checks for traffic violations. There are three primary types of violations monitored: parking violations, signal violations, and direction violations. A parking violation occurs when a vehicle remains stationary in a no-parking zone for a predefined period. If the system detects a vehicle in such a zone for longer than the allowed time, it is flagged as a parking violation. Signal violations are identified when a vehicle crosses a designated line on the road while the traffic signal is red. The system monitors the position of vehicles and determines whether they breach the line during a red light. Direction violations occur when a vehicle travels in the wrong direction. This is detected by tracking the vehicle's movement over time and comparing its current and previous positions to determine its trajectory. If the direction deviates from the permitted flow, it is flagged as a violation [110-115].

To assist in detecting signal violations, a traffic line is drawn over the road in the video footage preview. This line represents the boundary that vehicles must not cross during a red light. The system assigns green bounding boxes to detected objects under normal conditions. However, if a vehicle crosses the traffic line while the signal is red, the bounding box changes to red, indicating a violation. This visual representation allows operators to quickly identify and review violations captured in the footage. The system employs a database to manage and store all the relevant data. SQLite is used as the database management system, integrating seamlessly with

Python for efficient data handling [116-119]. The database is designed with a relational structure using BCNF (Boyce-Codd Normal Form) and consists of five tables: Cars, Rules, Cameras, Violations, and Groups. Each table serves a specific purpose in organizing the data for the application.

The Cars table records information about vehicles detected by the cameras. Each car is represented as a unique entity with several attributes: a unique identifier (id), color (color), license plate number (license), the location where the car was first sighted (first_sighted), an image of the license plate (license_image), an image of the car (car_image), the number of rules broken by the car so far (num_rules_broken), and the owner's name (owner). This table provides comprehensive information about every detected vehicle and its associated data. The Rules table stores all the rules enforced by the system. Each rule is described with a name and a corresponding fine for violating it. This table acts as a reference for determining the type of violation and the penalty associated with it. The Cameras table holds information about the cameras deployed in the system, including their unique identifiers and locations. It helps track which camera captured specific events or violations.

The Violations table integrates data from other tables to create a semantic record of traffic violations. It uses foreign keys to reference the Cars, Rules, and Cameras tables, establishing relationships between detected vehicles, broken rules, and the cameras that recorded the violations. For example, a record in this table may indicate that a car with a specific ID broke a particular rule at a certain time, as captured by a designated camera.

Finally, the Groups table organizes cameras into groups based on their locations or functions. Each group is assigned a unique name, allowing the system to manage and monitor cameras more effectively. This grouping enables operators to analyze data and monitor specific areas with ease. In summary, the traffic violation detection system employs a combination of advanced image processing techniques, machine learning models, and a robust database structure to monitor and enforce traffic regulations. By leveraging technologies like YOLOv3 and SQLite, the system ensures accurate detection, classification, and documentation of violations. This comprehensive approach enhances traffic management and promotes road safety by identifying and addressing violations effectively.

Paper Description

Traffic violation detection systems have been deployed globally to monitor and enforce traffic laws, utilizing a variety of technologies to improve road safety and ensure compliance with regulations. One of the most common systems is red-light cameras, which are installed at intersections to capture images or videos of vehicles running red lights. These systems detect violations when a vehicle crosses the stop line after the signal turns red. The captured evidence is used to issue citations to the vehicle's registered owner. Red-light cameras have proven effective in reducing accidents at intersections by deterring drivers from committing signal violations. Another widely used system is speed cameras, designed to monitor vehicle speeds on roads and highways. These cameras capture images or videos of vehicles exceeding the speed limit. Speed cameras can be either stationary, placed at fixed locations, or mobile, allowing enforcement officials to monitor speeds in different areas. By targeting speeding, these systems play a crucial role in reducing accidents caused by excessive speed, thereby improving overall road safety.

License Plate Recognition (LPR) systems are also an integral part of modern traffic enforcement. These systems use cameras equipped with optical character recognition (OCR) technology to read license plates. LPR systems serve multiple purposes, including identifying stolen vehicles, detecting unpaid tolls, and enforcing parking regulations. They are valuable for law enforcement and traffic management due to their ability to track vehicles and link them to registered owners. Automated Number Plate Recognition (ANPR) systems function similarly to LPR systems but are often employed in broader applications. ANPR systems monitor traffic flow, assist in toll collection, and enforce parking rules. They also play a significant role in identifying vehicles involved in criminal activities, providing authorities with crucial evidence for investigations. By integrating advanced analytics, these systems enhance traffic monitoring and contribute to improved security on roads.

These traffic violation detection systems collectively contribute to more efficient traffic management and law enforcement. By leveraging advanced technologies, they reduce manual intervention, enhance accuracy, and provide real-time data for quick action. Their deployment has shown significant success in deterring violations, improving compliance, and ultimately fostering safer driving behaviors. As technology evolves, these systems continue to be refined, integrating newer advancements to address emerging challenges in traffic management and enforcement.

Proposed System

The proposed advanced Traffic Signal Violation Detection System aims to enhance road safety and streamline traffic management by actively monitoring intersections and detecting violations in real time. A network of strategically installed cameras captures live traffic data, which is processed using computer vision techniques to detect vehicles and track their movements. By integrating with traffic signal controls, the system determines the state of traffic lights and identifies violations such as running red lights, speeding, illegal turns, and lane violations through robust detection algorithms. Violation data is securely stored with timestamps, location information, and multimedia evidence, ensuring reliable documentation. When a violation occurs, real-time alerts are generated and transmitted to law enforcement or traffic management authorities for immediate action. A user-friendly interface allows operators to monitor and review violations efficiently, while automated reporting tools generate statistical insights for analysis and system improvement.

The system is designed with scalability to support an increasing number of cameras and intersections, ensuring adaptability for urban growth. It prioritizes privacy and ethical considerations, complying with legal requirements and offering options to redact sensitive information. By promoting responsible driving behavior and reducing traffic signal violations, this cost-effective and privacy-compliant solution contributes to safer and more efficient urban roadways.

Results And Discussions

The proposed Traffic Signal Violation Detection System aims to revolutionize traffic enforcement and enhance road safety by employing advanced technology for real-time monitoring and violation detection. This system is envisioned to actively monitor intersections and roadways using strategically installed cameras to capture live traffic data. These cameras provide a comprehensive view of traffic flow and vehicle movements, forming the foundation for effective detection of violations. The captured video and images undergo processing through advanced computer vision techniques to analyze traffic patterns, detect vehicles, and track their movements in real time. By synchronizing with traffic signal controls, the system determines the status of traffic lights and accurately identifies violations, such as running red lights, illegal turns, speeding through intersections, and lane violations.

To ensure accurate detection, the system employs sophisticated violation detection algorithms. These algorithms are designed to differentiate between normal traffic behavior and violations, minimizing errors such as false positives, where non-violations are incorrectly flagged, and false negatives, where actual violations go undetected. Each violation is securely recorded in a database, accompanied by essential information such as timestamps, location details, and multimedia evidence. This allows for a robust documentation process that ensures violations can be reviewed and verified as needed. To further streamline enforcement, the system generates real-time alerts for detected violations, which are immediately transmitted to law enforcement or traffic management authorities. This rapid alert mechanism enables timely intervention, reducing the chances of repeat offenses and enhancing overall compliance with traffic laws.

The system includes a user-friendly interface that facilitates efficient review of detected violations by operators. Through this interface, operators can access detailed reports, review evidence, and issue penalties seamlessly. Additionally, automated reporting tools generate statistical insights into traffic patterns, violation trends, and system performance. These insights can be used to refine traffic management strategies, improve system accuracy, and address emerging traffic issues. By integrating these components, the Traffic Signal Violation Detection System aims to not only enforce traffic laws effectively but also optimize the overall traffic flow, reducing congestion and enhancing road safety.

Despite its advantages, implementing such a system presents significant challenges. Traffic conditions vary widely, influenced by factors such as weather, lighting, and traffic density. The system must be designed to function accurately under diverse conditions, ensuring reliable operation regardless of external variables. Image quality and resolution also play a critical role in detection accuracy. Low-quality footage may hinder the system's ability to identify violations, especially in scenarios involving partial or complete occlusion of vehicles or traffic signals. Objects such as trees, buildings, and shadows can further complicate detection by obscuring critical elements within the camera's field of view. Additionally, complex intersections with multiple lanes and signal configurations require the system to interpret a variety of scenarios accurately, demanding advanced algorithmic capabilities.

Hardware maintenance is another crucial aspect of system reliability. Cameras and sensors must be regularly calibrated and maintained to ensure optimal performance. Failures or malfunctions can result in system downtime, compromising enforcement capabilities. Moreover, data privacy concerns must be addressed, as the system captures and stores images and videos from public spaces. Ensuring compliance with data protection laws and implementing robust privacy safeguards is essential to gain public trust and mitigate ethical concerns. Efficient data storage and retrieval mechanisms are equally important, as the system generates vast amounts of data that must be managed effectively for long-term use.

Scalability poses another challenge, as the system must accommodate an increasing number of intersections and cameras without compromising performance. Integrating the system with existing traffic management infrastructure adds to the complexity, requiring seamless communication between components to maintain efficiency. Legal and regulatory challenges further complicate implementation, as traffic enforcement and data privacy laws vary across jurisdictions. Navigating these legal frameworks is essential to ensure the system's compliance and legitimacy. Cost is another critical consideration. Developing, deploying, and maintaining such a system requires significant investment, necessitating a focus on cost-effective solutions to make it feasible for widespread adoption. Additionally, the system must be designed to adapt to technological advancements, ensuring that it remains relevant and efficient over time. Public acceptance and cooperation are also vital, as resistance to automated traffic enforcement can hinder the system's effectiveness. Vandalism and tampering further threaten the system's integrity, requiring robust security measures to prevent unauthorized interference.

The types of violations the system targets reflect its comprehensive approach to traffic enforcement. Running red lights is one of the most common and dangerous violations, often resulting in severe collisions at intersections. By detecting and penalizing such behavior, the system aims to reduce the frequency of these incidents and enhance intersection safety. Similarly, failure to stop at stop signs poses significant risks, as vehicles rolling through intersections can cause collisions with other vehicles or pedestrians. Speeding through yellow lights is another hazardous behavior, as drivers attempting to beat the light may collide with vehicles entering the intersection. The system addresses this issue by monitoring vehicle speeds and flagging instances where drivers fail to stop when required.

Illegal turns on red lights, whether left or right, are also a focus of the system. These violations can lead to collisions with oncoming traffic or pedestrians, particularly in areas where such turns are prohibited. Pedestrian signal violations are another critical concern, as pedestrians ignoring

"Don't Walk" signals can cause accidents in high-traffic areas. Blocking intersections, where vehicles enter without sufficient space to clear, disrupts traffic flow and creates gridlock, impacting emergency vehicle access. The system monitors and penalizes this behavior to maintain smooth traffic movement.

U-turn violations, particularly in prohibited areas, are targeted to prevent unexpected traffic disruptions and collisions. Illegal lane changes at intersections, where drivers fail to follow designated lane markings, are also monitored, as such actions can lead to sideswipe collisions or confusion among other drivers. Crosswalk violations, where drivers fail to yield to pedestrians, are another priority, as these endanger pedestrian safety, especially at busy intersections. Left turns on red from two-way streets, which are illegal in many jurisdictions, are also detected and penalized to ensure compliance with traffic laws.

The system's focus on these violations underscores its commitment to improving traffic safety and promoting responsible driving behavior. By addressing a wide range of violations, the system seeks to create a safer and more orderly driving environment. Its implementation is expected to result in fewer accidents, improved traffic flow, and enhanced public confidence in traffic enforcement. Through its advanced capabilities, the Traffic Signal Violation Detection System represents a significant step forward in modernizing traffic management and ensuring safer urban roadways.

Conclusion

The designed algorithm successfully detects the specified violation, namely denying traffic signals, by identifying vehicles that fail to comply with traffic signal rules. The system's detection process is unique due to the differing threshold conditions required for this type of violation. While effective, the system processes one data set at a time, which limits its scalability and efficiency. Additionally, the program runtime is relatively slow, which can be addressed by deploying the system on a computer with high-speed processor specifications or utilizing GPU support for enhanced performance. Future research could focus on optimizing the algorithm by integrating advanced image processing techniques, potentially improving runtime by eliminating unnecessary steps in the background difference method. By incorporating a computer vision algorithm, the system could gain greater intelligence, making detection faster and more accurate. These advancements would streamline the processing workflow and enhance overall efficiency. To further improve the system's robustness, implementing number plate detection with Optical Character Recognition (OCR) support is planned. This feature would allow for automated identification of violating vehicles, linking them to their registered owners. OCR integration would not only enhance the system's functionality but also strengthen its ability to enforce traffic laws more effectively. Such enhancements would expand the system's application potential, making it a more comprehensive solution for traffic violation detection while paving the way for broader adoption in real-world scenarios.

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