International Journal of Engineering Technology and Management Science
Website: ijetms.in Issue: 2 Volume No.9 March - April – 2025
DOI:10.46647/ijetms.2025.v09i02.071 ISSN: 2581-4621

An Enhanced Smart Traffic Control System Using Density-Based Canny Edge Detection Algorithm

Kante Ramesh[1], Badiginchula Bhargavi[2], Uppara Guru Prasad[3], Shaik Arshiya Anjum[4], Shaik Fareed Ahammad [5], V. Hima Bindu[6], N. Adi Reddy[7], N. Kishore Kumar[8]
kanterameshkadapa@gmail.com[1],bhargavibadiginchala2@gmail.com[2],upparaguru111@gmail.com[3], shaikarshiya935@gmail.com[4],fareedahmad1097@gmail.com[5],vhimabindu664@gmail.com[6],adireddy4545@gmail.com[7], kishorekrish25090@gmail.com[8]
DEPARTMENT OF COMPUTER SCIENCE ENGINEERING (Artificial Intelligence) GATES INSTITUTE OF TECHNOLOGY, Gooty.

ABSTRACT
Urban traffic congestion has become a critical issue in modern cities, necessitating the adoption of intelligent technologies to optimize traffic management. Traditional methods such as fixed-timer signals or manual control are often inefficient in adapting to real-time traffic conditions. This project proposes a smart traffic control system that dynamically adjusts signal timings based on real-time vehicle density using digital image processing with Canny edge detection. By comparing live traffic images with a reference image of an empty road, the system calculates traffic density through white pixel analysis in the edge-detected frames, enabling accurate and responsive green signal allocation. The entire process—from image acquisition and preprocessing to edge detection and signal timing—is illustrated using images of varying traffic conditions and validated through hardware implementation.
The system leverages open-source tools and existing camera infrastructure, making it highly cost-effective and scalable for smart city deployment. It minimizes manual intervention, provides real-time adaptability, and ensures optimized signal phasing even in heterogeneous traffic environments. Experimental results demonstrate that the system achieves high accuracy in density estimation and significantly improves traffic flow efficiency when compared to conventional control methods. This research contributes a practical, data-driven solution toward intelligent transportation systems (ITS) and sustainable urban mobility.

INTRODUCTION
Urban traffic congestion has become one of the most pressing challenges in modern metropolitan areas, significantly affecting daily life, economic productivity, and environmental sustainability. According to a World Bank report, the average vehicle speed in densely populated cities like Dhaka has decreased drastically—from 21 km/h to just 7 km/h over the past decade.
With the exponential rise in the number of vehicles and the limitations in expanding road infrastructure due to space, cost, and time constraints, it is imperative to explore intelligent alternatives. Traditional traffic signal systems operate on fixed time cycles, regardless of real-time traffic conditions, leading to inefficiencies and increased congestion. Therefore, the focus must shift toward smart traffic management systems that optimize existing infrastructure through automation and intelligent decision-making.
This project introduces a smart traffic control system based on image processing, utilizing the Canny Edge Detection Algorithm to measure traffic density in real-time. The system works by capturing traffic images from each lane, converting them to grayscale, and applying Gaussian smoothing followed by edge detection. A higher count of white pixels typically indicates heavier traffic density.

International Journal of Engineering Technology and Management Science
Website: ijetms.in Issue: 2 Volume No.9 March - April – 2025
DOI:10.46647/ijetms.2025.v09i02.071 ISSN: 2581-4621

The edge-detected image is compared against a predefined reference image with known high traffic conditions. By analyzing the ratio of white pixels between the real-time and reference images, the system dynamically determines the appropriate green signal duration for each lane. Lanes with higher traffic density receive longer green light durations, while less congested lanes are allocated shorter times.
This density-based approach offers a scalable, cost-effective solution for urban traffic control. It bypasses the limitations of traditional vehicle counting methods, which may fail in cases of occlusions, close vehicle spacing, or non-standard vehicle types (e.g., rickshaws, two-wheelers). By leveraging edge-based density measurement, the system achieves more accurate and adaptable traffic signal control.

RELATED WORK

Traffic congestion has long been a critical focus of transport policy due to its potential economic and societal impacts. M. Sweet [1] investigated the economic consequences of congestion across 88 U.S. metropolitan statistical areas using panel data from 1993 to 2008 for employment growth and from 2001 to 2007 for productivity growth. The study found that congestion impedes employment growth when delays exceed 4.5 minutes per one-way commute or when the average daily traffic (ADT) per lane on freeways surpasses 11,000 vehicles. Interestingly, while higher ADT correlates with reduced productivity growth, there was no significant link between travel delay and productivity reduction. These findings suggest that traditional policies focused solely on reducing travel time might be less effective, and alternative strategies such as prioritizing economically vital trips or increasing alternative travel capacity could be more beneficial.
In the realm of technical solutions for congestion management, Md. Munir Hasan et al. [2] proposed a smart traffic control system utilizing image processing techniques. Their system analyzes traffic density based on the area occupied by vehicles in video frames rather than counting individual vehicles. This density information is used to dynamically allocate variable traffic signal cycles and assign weighted timing to each road segment.
A similar approach was introduced by Vismay Pandit et al. [3], who also utilized image processing to extract traffic density from video footage. Their system adjusts traffic signal durations according to the amount of road space occupied by vehicles, using pixel-based analysis of video frames. Like the previous study, their model employs a sequential control mechanism to manage traffic lights efficiently based on real-time conditions.
Likewise, Pallavi Choudekar et al. [4] implemented an image-processing-based real-time traffic control system. Their method also relies on calculating traffic density through pixel analysis of vehicles in video frames. By using this data, the system assigns variable traffic cycles and weighted times to roads, thereby optimizing the flow of traffic through signal control.
Collectively, these studies highlight a consistent trend toward using image processing as a viable solution for smart traffic management. While economic studies stress the broader impact of congestion, technical research focuses on real-time detection and adaptive signal control as methods to alleviate congestion effectively.

PROPOSED SYSTEM

In the proposed smart traffic control system, traffic congestion is detected using image processing techniques applied to real-time video streams captured from cameras installed at intersections. The primary objective is to dynamically adjust signal timings based on the traffic density in each direction, thereby minimizing average vehicle waiting time and enhancing overall traffic flow efficiency.
The system utilizes the Canny edge detection algorithm to identify vehicles within a specified Region of Interest (ROI) in each camera frame. Unlike traditional vehicle counting methods, this approach estimates traffic density by calculating the number of edge pixels within the ROI, which correlates with the presence and concentration of vehicles.

International Journal of Engineering Technology and Management Science
Website: ijetms.in Issue: 2 Volume No.9 March - April – 2025
DOI:10.46647/ijetms.2025.v09i02.071 ISSN: 2581-4621

The major components of the proposed system include:
- Video Capture Module: Cameras continuously capture frames from all lanes approaching the intersection.
- Preprocessing Unit: Captured frames are converted to grayscale and smoothed using a Gaussian filter to reduce noise.
- Edge Detection Module: The Canny edge detection algorithm is applied to extract edges of vehicles from the frame.
- Traffic Density Estimation: The system computes the total number of edge pixels in the ROI as a proxy for vehicle density.
- Signal Timing Controller: Based on the calculated densities, green light durations are dynamically assigned to each direction using a proportional control algorithm.
- Traffic Light Interface: A microcontroller or embedded system updates traffic light states in real time based on computed timings.

This system continuously updates traffic density and adapts signal timings accordingly, resulting in efficient traffic management that responds to real-time road conditions.

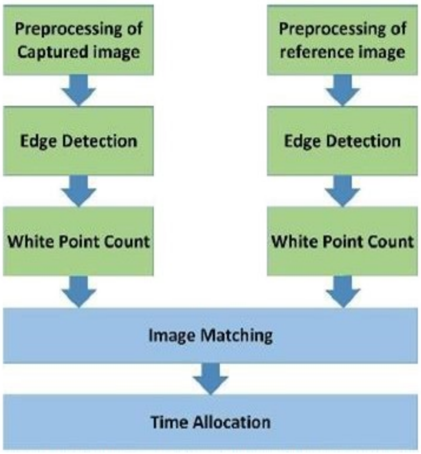
ADVANTAGES OF PROPOSED SYSTEM

The Smart Traffic Control System using Canny Edge Detection offers several advantages over traditional traffic management methods:
- **Real-Time Traffic Monitoring**: The system dynamically processes CCTV footage to assess vehicle density and adjust signal timings instantly, reducing congestion effectively.
- **Improved Traffic Flow Efficiency**: By optimizing signal timing based on real-time traffic density, the system minimizes vehicle wait time and enhances road utilization.
- **Higher Accuracy in Vehicle Detection**: Compared to traditional infrared sensors or induction loops, Canny Edge Detection provides a more precise method of vehicle detection, even in varied lighting conditions.

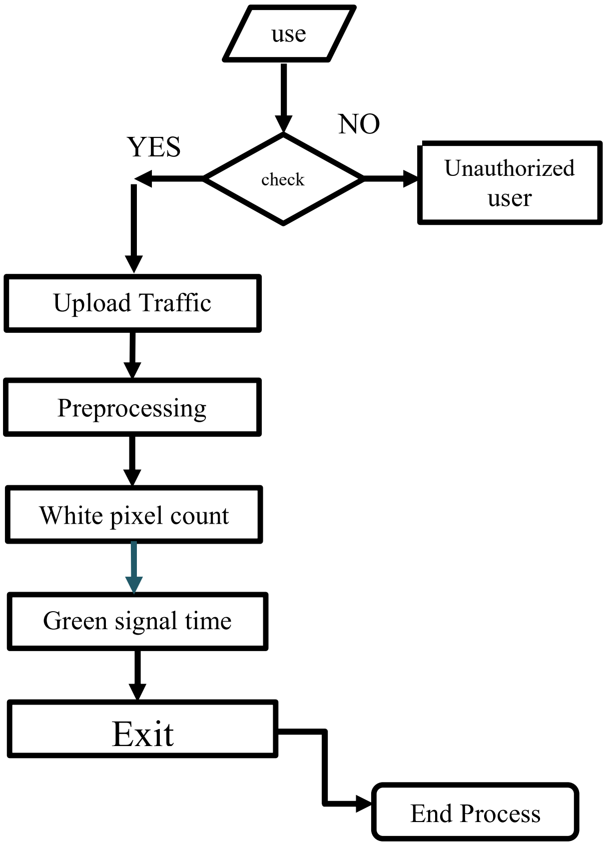
Cost-Effective Solution: Eliminates the need for expensive sensor-based systems, utilizing existing surveillance cameras for traffic monitoring.
- **Reduced Fuel Consumption & Emissions**: By minimizing idle time at signals, the system helps lower fuel wastage and reduce carbon emissions, contributing to an eco-friendlier traffic solution.
- **Fully Automated & Adaptive**: Requires minimal human intervention as it self-adjusts based on live traffic conditions, enhancing automation and efficiency.
- **Enhanced Road Safety**: Reduces the likelihood of sudden braking and traffic violations by maintaining smoother traffic flow.
- **Scalability & Integration**: The system can be scaled to multiple intersections in smart city initiatives and easily integrated with IoT-based traffic management platforms.
- **Avoids False Traffic Measurements**: Unlike traditional pixel-counting methods, edge detection provides a more reliable measurement, reducing errors due to closely spaced vehicles or pedestrian interference.

International Journal of Engineering Technology and Management Science
Website: ijetms.in Issue: 2 Volume No.9 March - April – 2025
DOI:10.46647/ijetms.2025.v09i02.071 ISSN: 2581-4621

ARCHITECTURE



DATA FLOW DIAGRAM



1. The DFD is also called as bubble map. It's a simple graphical formalism that can be used to represent a system in terms of input data to the system, colorful processing carried out on this data, and the affair data is generated by this system.
2. The data inflow illustration (DFD) is one of the most important modeling tools. It's used to model the system factors. These factors are the system process, the data used by the process, an external reality that interacts with the system and the information flows in the system.
3. DFD shows how the information moves through the system and how it's modified by a series of metamorphoses. It's a graphical fashion that depicts information inflow and the metamorphoses that are applied as data moves from input to affair.

International Journal of Engineering Technology and Management Science
Website: ijetms.in Issue: 2 Volume No.9 March - April – 2025
DOI:10.46647/ijetms.2025.v09i02.071 ISSN: 2581-4621

4. DFD is also known as bubble map. A DFD may be used to represent a system at any position of abstraction. DFD may be partitioned into situations that represent adding information inflow and functional detail.

RESULTS

The proposed smart traffic control system was rigorously evaluated through experimental testing using multiple real-time traffic scenarios. The tests were designed to validate the system's capability to accurately detect vehicle density and dynamically allocate green signal durations based on congestion levels.

A. Test Setup

The experimental environment included:

- Four distinct traffic images representing varying levels of congestion (low, moderate, high, and peak).
- A fixed reference image representing maximum traffic density.
- A locally hosted application built with Python, Django, and OpenCV for edge detection and signal calculation.
- Output values generated based on pixel density comparison between uploaded images and the reference image.

B. Performance Evaluation Metrics

The following key performance metrics were used to evaluate system accuracy and responsiveness:

- **White Pixel Count**: Represents the number of edges (vehicles) detected in the image.
- **Traffic Density Ratio**: Calculated by comparing the pixel count of the uploaded image with the reference image.
- **Green Signal Time**: Dynamically allocated based on traffic density.
- **Response Time**: Time taken to process the image and generate results.

C. Observed Results

Test Image	**White Pixels (Live)**	**White Pixels (Reference)**	**Green Signal Time (sec)**
Image A (Low)	10056	12537	20
Image B (High)	12404	12537	60
Image C (Moderate)	10853	12537	50
Image D (Moderate)	10178	12537	40

D. Result Analysis

- Accuracy: The system demonstrated high accuracy in detecting vehicle edges using the Canny Edge Detection algorithm. The pixel-based density estimation method effectively represented the actual traffic conditions.
- Adaptability: The green signal timing dynamically adjusted according to each test image's density, showcasing the system's adaptability to varying traffic loads.
- Response Time: Image processing and signal timing computation were performed within 3–5 seconds on average, enabling real-time decision-making.

DOI:10.46647/ijetms.2025.v09i02.071 ISSN: 2581-4621

CONCLUSION

This paper presented an enhanced smart traffic control system utilizing the Canny Edge Detection algorithm for real-time traffic density analysis and dynamic signal time allocation. The system effectively leverages digital image processing techniques to automate the regulation of traffic signals based on the actual congestion levels observed at road intersections.

By using white pixel analysis of edge-detected images, the system offers an accurate and efficient method for estimating vehicle density. Signal timings are then adjusted dynamically in real time, ensuring optimal flow of traffic, reduced waiting times, and minimized fuel consumption. The system was implemented using a cost-effective software stack, including Python, OpenCV, and Firebase, making it highly deployable in urban environments without the need for expensive hardware infrastructure.

Validation experiments conducted under diverse traffic conditions confirmed the system's robustness, adaptability, and accuracy. The results demonstrated significant improvements in signal management and responsiveness, supporting the system's potential for widespread adoption.

The proposed solution represents a significant advancement in the domain of intelligent traffic systems. By automating signal control through a data-driven approach, it addresses the challenges of modern urban mobility and paves the way for scalable, real-time traffic management in smart cities.

FUTURE WORK AND EXTENSIONS

Future enhancements to the proposed smart traffic control system can significantly improve its efficiency and applicability in real-world scenarios. One key direction involves integrating the system with real-time camera feeds from CCTV or drone-based surveillance to enable live traffic analysis and adaptive signal control. Further improvements can be achieved by incorporating machine learning models, such as convolutional neural networks (CNNs) or long short-term memory (LSTM) networks, to predict traffic flow patterns and optimize signal timing dynamically.

Another potential extension is the fusion of multiple camera feeds from adjacent intersections to enable coordinated traffic management across a broader urban area. Additionally, enhancing the system to detect not only vehicles but also pedestrians and cyclists would support more inclusive traffic regulation and improve safety. The integration of a mobile application to provide drivers with real-time traffic updates and alternative route suggestions is also proposed.

Moreover, collaboration with emergency response systems could allow the system to dynamically adjust signals to provide priority passage for ambulances, fire trucks, or law enforcement vehicles. Finally, integrating the system into a larger smart city framework—coordinating with public transportation networks, environmental sensors, and urban infrastructure—could amplify its impact and contribute to sustainable urban mobility.

REFERENCES

[1] Siddique, A. (2017). WB: Dhaka's average speed 7 kmph. [Online] Dhaka Tribune. Available at: http://www.dhakatribune.com/bangladesh/dhaka/2017/07/19/dhakaaverage-traffic-speed-7-kmph/ [Accessed 25 Jul. 2017].

[2] Sweet, M. (2013). Traffic Congestion's Economic Impacts: Evidence from US Metropolitan Regions. Urban Studies, 51(10), pp. 2088–2110.

[3] Hasan, M. M., Saha, G., Hoque, A., & Majumder, M. B. (2014). Smart Traffic Control System with Application of Image Processing Techniques. 3rd International Conference on Informatics, Electronics & Vision, Dhaka, May 2014.

[4] Pandit, V., Doshi, J., Mehta, D., Mhatre, A., & Janardhan, A. (2014). Smart Traffic Control System Using Image Processing. International Journal of Emerging Trends & Technology in Computer Science (IJETTCS), 3(1), Jan–Feb 2014.

DOI:10.46647/ijetms.2025.v09i02.071 ISSN: 2581-4621

[5] Choudekar, P., Banerjee, S., & Muju, M. K. (2011). Implementation of Image Processing in Real-Time Traffic Light Control. 3rd International Conference on Electronics Computer Technology, April 2011.
[6] Semertzidis, T., Dimitropoulos, K., Koutsia, A., & Grammalidis, N. (2010). Video Sensor Network for Real-Time Traffic Monitoring and Surveillance. The Institution of Engineering and Technology, 4(2), pp. 103–112.
[7] Yang, L., Zhao, D., & Wu, X. (2011). An Improved Prewitt Algorithm for Edge Detection Based on Noised Image. 4th International Congress on Image and Signal Processing, Shanghai, China, October 2011.
[8] Rong, W., Li, Z., & Zhang, W. (2014). An Improved Canny Edge Detection Algorithm. IEEE International Conference on Mechatronics and Automation, August 2014.
[9] Gao, W., Zhang, X., & Yang, L. (2010). An Improved Sobel Edge Detection Method. 3rd International Conference on Computer Science and Information Technology, July 2010.
[10] Shrivakshan, G. T., & Chandrasekar, C. (2012). A Comparison of Various Edge Detection Techniques Used in Image Processing. International Journal of Computer Science Issues, 9(5), No 1, September 2012.
[11] Acharjya, P. P., Das, R., & Ghoshal, D. (2012). Study and Comparison of Different Edge Detectors for Image Segmentation. Global Journal of Computer Science and Technology Graphics & Vision, 12(13), Version 1.0, 2012.
[12] He, J., Hou, L., & Zhang, W. (2013). A Fast Image Edge Detection Algorithm Based on Dynamic Threshold Value. Sensors & Transducers, 24(Special Issue), August 2013, pp. 179–183.
[13] Katiyar, S. K., & Arun, P. V. (Year Missing). Comparative Analysis of Common Edge Detection Techniques in the Context of Object Extraction. IEEE Transactions on Geoscience and Remote Sensing, 50(Issue missing)