ISSN: 3107-6513

A Software Based Simulation That Calculates Vehicle Density Using Image Processing and Adjusts the "GREEN LIGHT" Duration Dynamically

Dharshan [#1], YogaShri[*2],

#Department of Computer Science, Rathinam College of Arts and Science (Autonomous), Coimbatore, Tamilnadu, India

dharshan9791@gmail.com

Abstract - *Traffic congestion at road intersections is a major issue caused by increasing vehicle numbers and inefficient fixed-time traffic signal systems that do not respond to real-time traffic conditions. This project proposes a software-based simulation that calculates vehicle density using image processing and dynamically adjusts the green light duration according to traffic flow. The system captures traffic images or video frames from multiple lanes and applies image processing techniques such as grayscale conversion, filtering, object detection, and vehicle counting to estimate the number of vehicles in each lane. Based on the detected density, green signal time is allocated proportionally, giving priority to lanes with heavier traffic. This adaptive control method helps reduce waiting time, fuel consumption, and congestion while improving traffic movement and road utilization. The simulation demonstrates better performance compared to traditional fixed-time traffic signals and can be further developed for real-world smart traffic management systems.*

Keywords - *Traffic Signal Control, Vehicle Density Estimation, Image Processing, Adaptive Traffic Management, Dynamic Green Light Timing, Traffic Congestion Reduction, Vehicle Detection, Smart Traffic System, Computer Vision, Simulation Model.*

1. INTRODUCTION

Traffic congestion has become a serious problem in modern cities due to rapid urbanization and the continuous increase in the number of vehicles on the roads. Intersections are the most common points where traffic delays occur, especially when conventional traffic signal systems use fixed timing methods without considering the actual number of vehicles waiting in each lane. This often results in longer waiting times, unnecessary fuel consumption, air pollution, and inefficient road usage. Therefore, there is a growing need for intelligent traffic control systems that can respond dynamically to changing traffic conditions.

This project presents a software-based simulation that calculates vehicle density using image processing and adjusts the green light duration dynamically. The system captures traffic images or video frames from different approaches of an intersection and processes them to detect and count vehicles. Based on the vehicle density, the signal timing is modified automatically, allowing lanes with higher traffic volume to receive longer green signals while reducing idle time for less congested lanes. This adaptive mechanism improves the overall traffic flow and reduces congestion.

The proposed system is designed as a simulation model to evaluate the effectiveness of dynamic traffic signal control before real-world implementation. It demonstrates how image processing techniques and intelligent decision-making can be integrated to create efficient traffic management solutions. This project can serve as a foundation for future smart city applications involving real-time traffic monitoring and automated signal systems.

2. RELATED WORKS

Several researchers have worked on intelligent traffic signal control systems to overcome the limitations of fixed-time traffic lights. Early systems mainly used sensors such as infrared, ultrasonic, and loop detectors to measure traffic density and adjust signal timing. These methods improved traffic flow to some extent, but they required additional hardware installation and regular maintenance. Later studies focused on adaptive traffic systems that dynamically allocate green signal time based on vehicle queue length and lane congestion, resulting in reduced waiting time and better intersection performance.

With the advancement of computer vision, image processing techniques became popular for traffic monitoring. Researchers developed systems that use cameras to capture road images and apply vehicle detection, background subtraction, contour analysis, and counting algorithms to estimate lane-wise vehicle density. These systems eliminated the need for physical sensors and provided more accurate real-time traffic data. Recent works have also used OpenCV and YOLO-based object detection models for identifying vehicles and dynamically controlling traffic signals based on density levels.

Recent studies further enhanced adaptive traffic control using machine learning and deep reinforcement learning techniques. These methods learn optimal signal timing strategies from traffic patterns and simulation environments, significantly reducing delays compared to conventional methods. Digital twin and smart city traffic management models are also being explored for real-time monitoring and control. Inspired by these developments, the proposed project uses image processing in a software-based simulation to calculate vehicle density and dynamically adjust green light duration efficiently.

3.System Design

The system is designed as a software-based traffic signal simulation that uses image processing to estimate vehicle density and dynamically control green light duration at road intersections. The architecture consists of input, processing, decision-making, simulation control, and output modules that work together to improve traffic flow efficiency.

3.1.Input Module

This module captures traffic images or video frames from cameras placed at each lane of the intersection. The collected data acts as the real-time input for analyzing traffic conditions. In the simulation environment, stored traffic videos or sample images can also be used.

3.2.Image Processing Module

The captured frames are processed using image processing techniques such as grayscale conversion, noise filtering, background subtraction, edge detection, and contour identification. These steps help in detecting moving vehicles and separating them from the road background.

3.3. Vehicle Density Calculation Module

After vehicle detection, the system counts the number of vehicles present in each lane. Based on the count, traffic density is calculated and categorized as low, medium, or high congestion level.

3.4. Decision-Making Module

This module compares vehicle density values from all lanes and determines the green signal duration dynamically. Lanes with more vehicles are given longer green light time, while lanes with fewer vehicles receive shorter durations.

3.5.Traffic Signal Simulation Module

The calculated timing values are applied in the simulation environment where red, yellow, and green lights are controlled automatically. The signal sequence changes continuously according to updated traffic density.

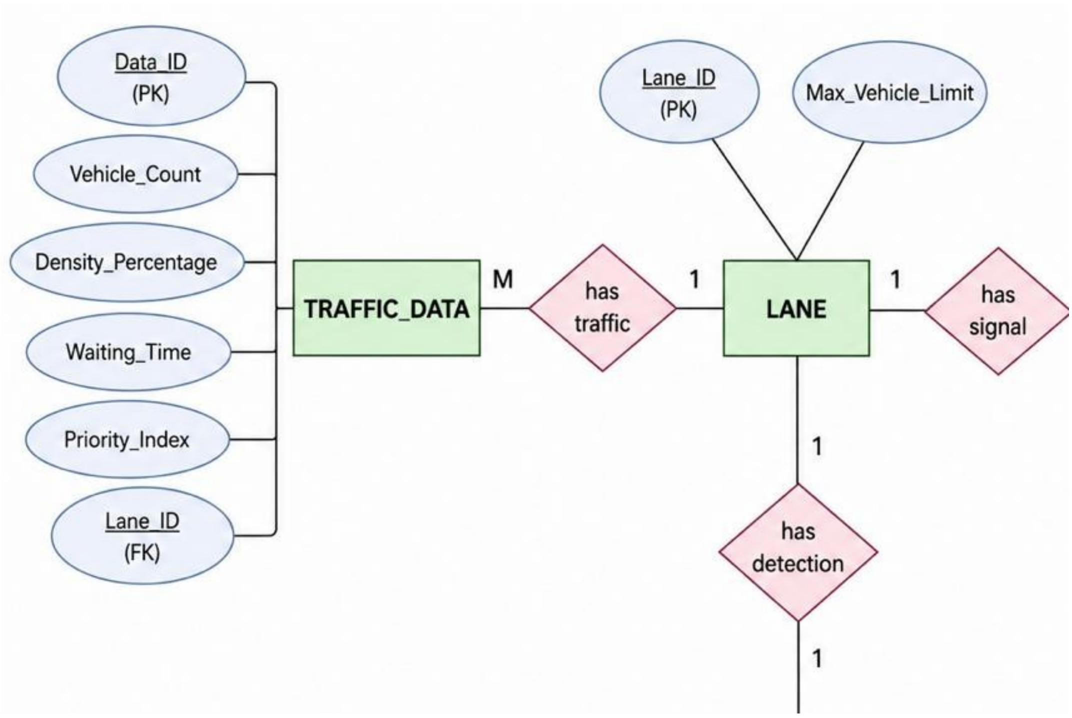
3.6. Output Module

The final output displays lane-wise vehicle count, traffic density status, signal timer, and active traffic light. Performance metrics such as reduced waiting time and improved traffic movement are also observed.

4.METHODOLOGY

The methodology of this project is based on developing a software simulation that uses image processing techniques to detect vehicle density and dynamically control traffic signal timing. Initially, traffic images or live video frames from multiple lanes are captured through cameras placed at an intersection. These images act as the input data for the system and are continuously updated to monitor real-time traffic conditions.The captured images are preprocessed using techniques such as grayscale conversion, noise removal, background subtraction, and edge detection to enhance image quality and isolate moving vehicles. After preprocessing, contour detection or object detection methods are applied to identify vehicles present in each lane. The detected vehicles are then counted, and the traffic density of each lane is calculated based on the total number of vehicles.

Once the density values are obtained, the system uses a dynamic timing algorithm to assign green signal duration proportionally. Lanes with higher traffic density receive longer green time, while less congested lanes receive shorter duration. The entire process is simulated in software, where traffic lights automatically switch between red, yellow, and green signals according to updated density values. The performance of the system is evaluated by observing reduced waiting time, smoother traffic flow, and better intersection efficiency compared to fixed-time traffic signals.



5.Outcomes and Disclosure

The proposed software-based traffic signal simulation successfully calculates vehicle density using image processing techniques and dynamically adjusts green light duration based on real-time traffic conditions. The system effectively detects and counts vehicles in different lanes, allocates signal timing according to congestion level, and improves the movement of vehicles at intersections. The simulation results show reduced waiting time, minimized traffic congestion, better fuel efficiency, and improved road utilization when compared to traditional fixed-time traffic signal systems.

The project demonstrates that image processing can be used as a cost-effective and intelligent solution for traffic management without requiring expensive physical sensors. It provides a scalable foundation for smart city transportation systems and can be further enhanced with machine learning, IoT devices, and cloud-based monitoring. However, system accuracy may depend on camera quality, weather conditions, lighting variations, and proper vehicle detection algorithms. Future improvements can focus on real-time deployment, emergency vehicle priority handling, and multi-junction traffic coordination.

6.Conclusion

The project successfully demonstrates a software-based traffic signal simulation that calculates vehicle density using image processing and dynamically adjusts green light duration according to real-time traffic conditions. By capturing traffic images and detecting vehicles in each lane, the system accurately estimates congestion levels and modifies signal timing accordingly. This helps in managing intersections more efficiently than traditional fixed-time traffic signal systems.
The adaptive signal control mechanism reduces unnecessary waiting time, minimizes traffic congestion, and improves the smooth movement of vehicles through road intersections. It also contributes to reduced fuel consumption and lower air pollution caused by vehicles idling at signals. The simulation results show that dynamic timing allocation provides better road utilization and overall traffic performance.

In conclusion, the project proves that image processing can be effectively used for intelligent traffic management applications. It offers a cost-effective and scalable solution that can be further enhanced with machine learning, IoT sensors, and real-time cloud monitoring systems. This work serves as a strong foundation for future smart city traffic control and automated transportation management.

References

1. R. C. Gonzalez and R. E. Woods, *Digital Image Processing*, 4th Edition, Pearson Education, 2018.

2. S. S. Beauchemin and J. L. Barron, “The Computation of Optical Flow,” *ACM Computing Surveys*, vol. 27, no. 3, pp. 433–466, 1995.

3. OpenCV Organization, *OpenCV Documentation*, Available: https://opencv.org/

4. R. Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2011.

5. M. A. Jabbar, B. L. Deekshatulu, and P. Chandra, “Intelligent Traffic Light Control System Using Image Processing,” *International Journal of Engineering Research and Applications*, vol. 5, no. 6, pp. 45–50, 2015.

6. A. K. Mittal and D. Bhandari, “A Novel Approach to Implement Green Wave System and Detection of Emergency Vehicles,” *International Journal of Computer Applications*, vol. 72, no. 7, pp. 18–22, 2013.

7. P. Viola and M. Jones, “Rapid Object Detection Using a Boosted Cascade of Simple Features,” *Proceedings of CVPR*, 2001.

8. World Health Organization, *Global Status Report on Road Safety*, Geneva, Switzerland, 2018.