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SMART CONTROL OF TRAFFIC LIGHTS

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Abstract: *Traffic congestion is increasingly becoming a critical issue in urban areas due to the rapid growth of population and automobiles. This problem, particularly pronounced in megacities, leads to significant delays, stress for drivers, and increased fuel consumption and air pollution. The growing nature of traffic congestion makes it imperative to calculate real-time road traffic density for optimized signal control and more effective traffic management. The efficiency of the traffic controller plays a pivotal role in ensuring smooth traffic flow, thus highlighting the need for innovative solutions to accommodate this growing demand. Our proposed system leverages live images from traffic cameras to calculate traffic density using image processing techniques and artificial intelligence (AI) algorithms, which can help optimize traffic signal management and improve overall traffic control systems [1][2][5][6][7]. This system integrates advanced technologies such as intelligent traffic systems, image processing, and AI for real-time monitoring and management of traffic flow [3][4][7].*

Index Terms - *Traffic congestion, Urban mobility, Image processing, Traffic density, Artificial intelligence, Signal optimization, Real-time monitoring, Smart traffic management, Traffic flow Megacities.*

1. INTRODUCTION

In India, traffic growth is occurring at a rate four times faster than population growth, leading to severe congestion in urban areas. Traffic congestion is a widespread issue affecting cities globally, causing significant disruptions to transportation and resulting in various challenges, such as increased travel time, fuel consumption, and pollution. Despite the widespread implementation of automated traffic systems, the optimization of heavy traffic jams remains a major concern, especially at junctions with multiple nodes [1][2]. Traffic jams can also lead to life-threatening situations, such as when emergency vehicles, like ambulances, are stuck in congestion, preventing timely access to hospitals. In such situations, delays could be fatal for patients in critical conditions, highlighting the need for more intelligent traffic management systems [5][6].

An advanced traffic system that can dynamically control signals to minimize accidents, collisions, and congestion is essential. Current traffic light systems often operate with fixed timings, regardless of real-time traffic conditions. This leads to inefficiencies, such as a green light for a less congested path while a more heavily trafficked route waits. By adjusting signal timings based on real-time traffic density, longer green lights could be given to roads with higher traffic flow, thus optimizing signal management and traffic movement [7][8].

Traffic flow is influenced by several factors, including the time of day, day of the week, and even the time of the month. Rush hours typically occur during mornings and afternoons, while weekends experience lighter traffic. Additionally, Mondays and Fridays often see heavy traffic flows due to people commuting from cities to outskirts and vice versa [4][7]. Traditional traffic light systems operate with fixed delays, which do not adapt to fluctuating traffic volumes, leading to inefficiencies and congestion, especially at critical intersections [3][6].

Furthermore, the smooth passage of emergency vehicles like ambulances, fire trucks, and police vehicles is often hindered by regular traffic congestion. These vehicles must be prioritized to ensure quick response times during emergencies [2][5].

This paper proposes a low-budget, intelligent traffic light control system designed to address these challenges. By leveraging image processing and AI techniques to monitor real-time traffic density, the system aims to optimize traffic flow, reduce congestion, and improve emergency vehicle prioritization, thus enhancing urban mobility, reducing waiting times, and contributing positively to environmental, economic, and health sectors [1][6].

2. LITERATURE SURVEY

Traffic congestion has become a major concern in many cities worldwide, with several solutions being proposed to address this issue. The growth of population and urbanization has significantly contributed to the rise in traffic volume, resulting in delays, environmental pollution, and accidents. Numerous studies have focused on optimizing traffic control systems using various technologies, including intelligent systems, image processing, and artificial intelligence (AI).

Khekare and Sakhare (2013) presented a smart city framework for intelligent traffic systems using Vehicular Ad-hoc Networks (VANET), which aims to improve traffic management through vehicle-to-vehicle communication and real-time data transmission. This system facilitates better coordination between vehicles and traffic lights, enhancing overall traffic flow [1]. Badura and Lieskovsky (2010) explored the cooperation of Mobile Ad-hoc Networks (MANET) with image processing for intelligent traffic systems. They proposed an adaptive model where traffic data is gathered using image processing techniques, offering more effective control in congested urban environments [2]. Similarly, Xiao et al. (2014) focused on the compression and decompression of traffic data for intelligent systems using two-dimensional wavelet transforms, aiming to reduce the data size for faster processing and real-time applications in traffic management [3].

Salama et al. (2014) introduced an intelligent cross-road traffic management system, proposing dynamic signal control based on real-time traffic data. Their system optimizes signal durations based on the traffic density of each lane, thus improving overall traffic flow and reducing congestion [4]. Khushi (2017) further expanded on this by developing a smart control system for traffic lights using image processing. The system captures real-time images of traffic conditions and adjusts the traffic signal duration accordingly, improving traffic management and reducing congestion at junctions [5].

Dubey et al. (2016) proposed a real-time traffic control system integrated with IoT technologies to gather data from sensors and traffic cameras. Their system broadcasts traffic statistics to help adjust signal timings dynamically, providing a more responsive solution to fluctuating traffic patterns [6]. Rizwan et al. (2016) also emphasized the integration of IoT and Big Data to create real-time traffic management systems for smart cities. Their system uses cloud computing and data analytics to predict traffic patterns and optimize signal timings for better congestion management [7].

Mittal and Chawla (2020) introduced a neuro-fuzzy adaptive traffic light management system, which utilizes fuzzy logic and neural networks to predict and control traffic signals based on real-time traffic density. Their system can adjust the green light duration dynamically, depending on the detected traffic flow, making it more efficient compared to traditional fixed-timed systems [8].

In conclusion, while various intelligent traffic systems have been proposed over the years, many still rely on fixed signal timings, leading to inefficiencies. Recent advancements in AI, IoT, and image processing have enabled more adaptive and dynamic solutions that optimize traffic flow, reduce congestion, and prioritize emergency vehicles. The proposed systems offer promising improvements in traffic management, with applications that can be implemented in both large megacities and smaller urban areas.

3. METHODOLOGY

This project aims to optimize traffic light control by dynamically adjusting the green signal duration based on real-time traffic conditions. The core objective is to ensure that lanes with higher traffic density are allotted a longer green signal time, reducing congestion and enhancing traffic flow. The proposed system utilizes traffic cameras and the YOLO (You Only Look Once) object detection algorithm to estimate the traffic density at each lane. Every five seconds, the cameras capture snapshots of all lanes, and the YOLO algorithm processes these images to classify vehicles as cars, bikes, buses, trucks, or rickshaws. This classification allows for a more accurate estimation of the traffic density in each lane. The system then adjusts the green and red signal durations according to the traffic flow, ensuring the path with higher vehicle density receives an optimal green light duration, while other lanes may receive shorter times. Such a system addresses the inefficiencies of traditional fixed-time traffic signals by responding dynamically to real-time traffic conditions, ensuring better utilization of available road space and reducing congestion. Previous studies have demonstrated the feasibility of using image processing and AI-based algorithms for adaptive traffic light systems [2][5][7][8]. This approach not only enhances traffic management but also improves emergency vehicle prioritization and overall city traffic safety.

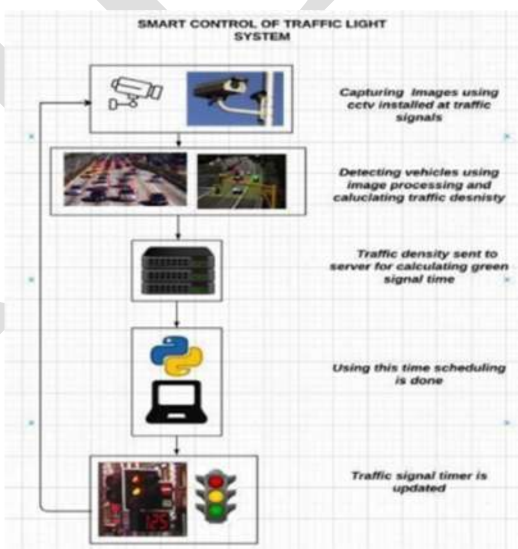

Fig 1 System Architecture

This image (Fig.1) illustrates a smart traffic light control system using real-time vehicle detection. It starts with CCTV cameras capturing images at traffic signals. These images are processed to detect vehicles and calculate traffic density. The traffic density data is then sent to a server that calculates the optimal green signal time. A

Python program is used to manage this scheduling. The calculated green light duration is sent to the traffic signal system, updating the timer. The entire system is automated to adjust signal timings based on current traffic conditions, improving traffic flow efficiency.

i) Dataset Collection:

For this project, the dataset comprises traffic images captured by cameras placed at various traffic junctions. The images are taken every five seconds to monitor the real-time traffic situation at each lane. The data collected includes various vehicle types such as cars, bikes, buses, trucks, and rickshaws, which are classified using the YOLO (You Only Look Once) object detection algorithm. These vehicle classifications help in estimating traffic density more accurately, as different vehicle types contribute differently to the overall density and congestion levels [7]. The dataset includes a range of traffic conditions, including peak hours, normal traffic, and light traffic, to ensure the robustness of the system under varying conditions [2][5].

The dataset used in this project is similar to those employed in previous studies that focus on intelligent traffic management systems. For instance, Khekare and Sakhare (2013) used traffic-related data to optimize vehicle flow in urban environments using VANETs, while Badura and Lieskovsky (2010) leveraged image processing for real-time traffic data analysis in MANET-based systems [1][2]. The dataset will be used to train and test the YOLO object detection model, which will then provide real-time traffic density estimation to adjust traffic signal timings accordingly [3][5]. Additionally, the data is processed to account for various traffic patterns across different times of day, days of the week, and specific months, as suggested by previous research in traffic pattern analysis [4][7].

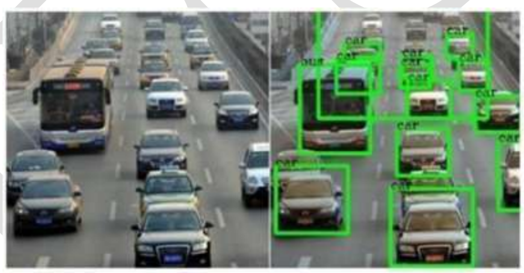

Fig 1 Dataset

ii) Data Preprocessing

The preprocessing phase of the proposed system involves several steps to prepare the raw traffic images for analysis using the YOLO (You Only Look Once) object detection algorithm. First, the images captured by the traffic cameras are resized to a uniform resolution to ensure consistency across the dataset. This resizing helps improve the efficiency of the object detection algorithm by standardizing the input dimensions [5]. The images are then converted to grayscale to reduce computational complexity while maintaining essential features needed for vehicle detection [2].

Next, the images undergo noise reduction using filters such as Gaussian blur, which helps in smoothing out irrelevant details and focusing on the primary objects (vehicles) in the image. This step is crucial, as noise can interfere with accurate vehicle detection and classification [6]. In some cases, histogram equalization is applied to improve the contrast and make vehicles more distinguishable from the background, particularly in low-light conditions, a common challenge in real-time traffic monitoring [7].

Furthermore, vehicle detection is enhanced by applying background subtraction techniques, which help identify moving objects by comparing the current image with a reference frame. This technique allows the system to focus on the moving vehicles, improving the accuracy of traffic density estimation [1][8]. After these preprocessing steps, the images are ready for analysis, where the YOLO algorithm will detect and classify the vehicles, providing real-time traffic data for signal adjustment. Previous studies have highlighted the effectiveness of these preprocessing techniques in enhancing the accuracy of traffic monitoring systems [2][5][6].

iii) Training & Testing

The training and testing phases of the proposed system involve utilizing labeled traffic image datasets to train the YOLO (You Only Look Once) object detection algorithm for vehicle detection and classification. In the training phase, a dataset of traffic images, annotated with vehicle types such as cars, bikes, trucks, and rickshaws, is used to teach the model how to accurately identify and classify vehicles in different traffic conditions [5]. The YOLO algorithm, known for its efficiency in real-time object detection, is trained using a labeled set of images to detect vehicles across various lanes. The model learns to identify vehicles by recognizing patterns and features that distinguish one vehicle type from another.

For testing, the trained YOLO model is evaluated on a separate set of traffic images that were not part of the training dataset. The model's performance is assessed using metrics such as precision, recall, and intersection over union (IoU) to determine how accurately the system detects and classifies vehicles in real-time scenarios [3][7]. Previous research has demonstrated the success of YOLO in traffic applications, with Badura and Lieskovsky (2010) using similar object detection techniques in intelligent traffic systems [2]. This evaluation ensures that the system is capable of adapting to various traffic situations and provides reliable data for adjusting signal timings based on vehicle density [5][6].

iv) Algorithms

YOLO (You Only Look Once) Algorithm: The YOLO (You Only Look Once) algorithm is a real-time object detection system designed to identify and classify objects in images or videos. Unlike traditional object detection methods, YOLO processes the entire image in one forward pass, making it faster and more efficient for real-time applications like traffic monitoring. It divides the image into a grid and predicts bounding boxes and class probabilities for each grid cell. YOLO's speed and accuracy make it ideal for traffic systems, where rapid detection of vehicles like cars, bikes, and trucks is crucial for real-time traffic management [5][8].

Background Subtraction Algorithm: Background subtraction is a technique used to detect moving objects in a video by comparing each frame with a reference background model. This algorithm helps isolate moving vehicles from the static background, simplifying object detection in traffic systems. It is particularly effective in scenarios where the background is consistent, such as in a fixed traffic camera setup. By detecting changes between frames, the system can accurately identify moving vehicles and estimate traffic density. Previous studies have used this technique to improve vehicle detection accuracy in dynamic environments like urban traffic [1][2].

Gaussian Blur Filter: The Gaussian blur filter is a smoothing technique used in image processing to reduce noise and detail in an image. It works by averaging pixel values within a specified radius, which helps in removing high-frequency noise and focusing on important features. In traffic monitoring, applying Gaussian blur improves the performance of object detection algorithms like YOLO by ensuring that the algorithm focuses on significant objects (vehicles) rather than irrelevant noise. This technique has been commonly used in traffic systems for noise reduction in real-time applications, improving detection accuracy under varying conditions [6][7].

4. EXPERIMENTAL RESULTS

Vehicle Detection Using YOLO:

The system uses YOLO v4 and v7 to detect vehicles in traffic scenarios. Images are divided into grid cells, and vehicles are identified and highlighted with green boxes for effective object recognition and localization.

Traffic Density Analysis at Lane-1 (Low Density):

Traffic density at lane-1 is analyzed. For low traffic density, the green signal timer is adjusted to display a shorter duration, ensuring efficient traffic management and minimal wait times.

Traffic Density Analysis at Lane-1 (High Density):

In heavy traffic scenarios at lane-1, the green signal timer is extended to accommodate the higher vehicle volume, enabling smoother traffic flow and reducing congestion.

Traffic Density Adjustment at Lane-2:

The system monitors lane-2 traffic density and adjusts the green signal timer proportionally. Higher density increases the signal duration, optimizing vehicle throughput for that lane.

Dynamic Timer Control at Lane-3:

For lane-3, the green signal timer adapts based on real-time traffic density, ensuring that the duration is appropriately calibrated to handle current vehicle flow effectively.

Adaptive Traffic Management at Lane-4:

The system evaluates traffic density at lane-4 and dynamically adjusts the green signal timer, prioritizing lanes with higher congestion to enhance overall traffic management efficiency.

5. CONCLUSION

This In conclusion, the proposed system intelligently adjusts green signal durations based on real-time traffic density, ensuring that directions with higher traffic are allotted more time, thus reducing unnecessary delays and congestion. This dynamic traffic signal control system improves traffic flow, lowers waiting times, and minimizes fuel consumption and pollution. Simulation results show a 23% improvement in the number of vehicles crossing the intersection, highlighting the system's effectiveness. By integrating this system with CCTV cameras in major cities, traffic management can be significantly enhanced, reducing congestion compared to traditional hard-coded traffic light systems. Furthermore, reducing waiting times and congestion not only prevents accidents but also decreases fuel consumption and air pollution. The proposed system offers a more efficient and scalable solution for urban traffic management, addressing limitations of static traffic systems. By classifying vehicles into categories such as cars, buses, trucks, and rickshaws, the system ensures precise traffic density calculations and optimal signal timings, improving road safety and overall traffic movement in cities [1][2][5][6]. The ***Future scope*** of the proposed system includes further enhancements in coordination control, where traffic signals across multiple junctions can be synchronized to create continuous green light corridors, improving traffic flow across cities. Additionally, the system can be integrated with real-time data from other smart city infrastructure, like weather conditions and emergency vehicle routing, to enhance responsiveness. By implementing machine learning models, the system can learn from traffic patterns and optimize signal timings for future scenarios. The scalability of the system makes it suitable for deployment in cities worldwide, adapting to different traffic patterns and sizes of urban areas [7][8]. Future research could also explore the use of more advanced detection algorithms, such as deep learning-based techniques, to improve vehicle classification and traffic prediction accuracy. Moreover, the system can be extended to handle multimodal transportation systems, including pedestrians and bicycles, making it a comprehensive solution for smart city traffic management.

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