International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 07 | July - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

AI Based Smart Traffic Management

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Abstract - A smart city's traffic management system is one of its key components. Road traffic is frequently congested due to the metropolitan cities' rapid population expansion and urban mobility. In this work, a smart traffic management system utilizing the Internet of Things (IoT) is presented to address a variety of challenges for managing traffic on roadways and to aid authorities in efficient planning. Road traffic flow is optimized using a hybrid strategy (a combination of centralized and decentralized), and diverse traffic scenarios are effectively managed using an algorithm. In order to achieve this, the system adjusts traffic signals after receiving input on traffic density from cameras, sensors, and other devices. To reduce traffic congestion, a different artificial intelligence-based method is utilized to forecast future traffic density. Additionally, during a traffic jam, RFIDs are utilized to give priority to emergency vehicles like ambulances and fire brigade vehicles. Smoke sensors are also a component of this system to detect a fire on the road. A prototype is created that not only improves traffic flow but also connects adjacent rescue departments with a centralized server to show the usefulness of the proposed traffic management system. Additionally, it harvests helpful data that is presented in graphical formats, which could aid the government in future road design.

***Key Words*:** Traffic control, Traffic light system, Traffic management, Object detection Intelligent transport systems, Smart surveillance, Computer Vision, YOLO, Machine Learning.

1.INTRODUCTION

Efficient and reliable transportation systems are crucial for a country's economic growth. However, poor management and traffic congestion result in wasted time, fuel, and money. To overcome these issues, it is imperative to have a fast, cost-effective traffic control system. Intelligent control methods and automation can greatly improve traffic flow and safety. As the number of vehicles on the road increases, intelligent traffic control becomes increasingly important. While there are various techniques to manage traffic and prevent congestion, no single technique is perfect due to the constantly changing nature of real-time traffic situations. Therefore, it is necessary to develop adaptive traffic management strategies that can adjust to changing circumstances. These strategies can allocate time to traffic lights based on traffic density, prioritize ambulances, and display obstacle detection messages to enhance convenience. With the growing population and number of vehicles in cities, efficient traffic management has become a significant challenge. Existing traffic management systems often fail to address real-time traffic scenarios effectively, leading to inefficiencies. This project proposes using Python OpenCV software and image processing techniques to implement a traffic management system aimed at reducing congestion. By analyzing traffic density from camera footage, the system can send commands to traffic lights to optimize signal timing and control traffic flow. Intelligent Transportation Systems, including intelligent traffic light control, are essential components of modern transportation techniques, improving road safety and efficiency. As people increasingly rely on personal vehicles for commuting, traffic congestion has become a major problem. While it is not feasible to restrict personal vehicle usage, traffic flow can be managed effectively to mitigate congestion issues. Smart city initiatives, such as Intelligent Transport Systems, are being implemented to monitor traffic signals in real-time and adjust signal timing based on the number of cars on the road. Various detection methods can be employed to accurately determine car volumes.

2. BODY OF PAPER

SECTION 2.1 PROBLEM DEFINITION

The existing method of traffic control, which utilizes the Traffic Light System, has a drawback in that it relies solely on a predetermined numerical value loaded into a timer for each phase. This means that regardless of the actual traffic conditions, the lights are set to turn on and off at specific intervals for different lanes. This can result in a green light being displayed even when a lane is empty, leading to inefficient use of resources.

To address this issue, another method that has been used is the utilization of sensors. These sensors collect traffic information for specific lanes and based on this information, the traffic lights can be adjusted. However, the problem with this approach is that the traffic information provided by the sensors is limited in scope. It may not capture the complete picture of traffic density or consider other factors that could affect traffic flow.

The main objective of implementing a traffic management system is to allocate time to each lane based on its density. This means that lanes with higher traffic density would receive more time for green signals, allowing for smoother traffic flow.

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Additionally, it is crucial to provide maximum priority to lanes where emergency vehicles, such as ambulances, are present. This ensures that they can navigate through traffic quickly and efficiently, potentially saving lives.

By incorporating advanced technologies and intelligent algorithms, a traffic management system can dynamically adjust signal timings based on real-time traffic conditions and prioritize lanes accordingly. This approach takes into account the actual traffic density, rather than relying on fixed timers or limited sensor data. It can lead to optimized traffic flow, reduced congestion, and improved overall efficiency of the transportation system.

SECTION 2.2 PROBLEM SOLUTION

The proposed techniques for controlling traffic signals using image processing algorithms involve several steps:
Image acquisition: This step involves capturing images or video footage of the traffic scene using cameras or sensors installed at strategic locations. These images serve as input for further processing.

Image enhancement: The acquired images may undergo enhancement techniques to improve the quality and clarity. This can include adjusting brightness, contrast, and other parameters to enhance the visibility of objects and vehicles in the image.

Preprocessing: In this step, the acquired and enhanced images are preprocessed to extract relevant information and remove any unwanted noise or artifacts. This can involve techniques such as image filtering, edge detection, and image segmentation.

Vehicle density measurement through IP and ML: Using image processing and machine learning techniques, the processed images are analyzed to estimate the density of vehicles in each lane or area. This can be achieved by detecting and tracking vehicles in the images, counting the number of vehicles, and estimating their spatial distribution.

Traffic signal operation: Based on the vehicle density measurements obtained from the image processing algorithms, the traffic signal operation is dynamically adjusted. The system can use the values received from OpenCV, a popular computer vision library in Python, to determine the appropriate timing and sequence of signal changes for each lane or intersection.
By continuously monitoring and analyzing the traffic conditions through image processing, the traffic signal control system can adapt and optimize the signal timings in real-time. This allows for efficient traffic management by allocating more green time to lanes with higher vehicle density and facilitating the smooth flow of traffic.

SECTION 2.3 METHODOLOGY

The working methodology for calculating the green signal time based on the number of vehicles of each class at a signal is as follows:
Capture Image: The system captures an image from the CCTV cameras at the traffic junction when the time of the signal that is about to turn green next is 1 second.

Vehicle Detection: The captured image is processed using the YOLO vehicle detection algorithm. The algorithm identifies and detects vehicles of different classes such as cars, bikes, buses, trucks, and rickshaws. The number of vehicles of each class is counted. Average Time Calculation: The system calculates the average time required for each class of vehicle to cross the intersection. This is based on factors like the average speed of each class of vehicle when the green light starts and the acceleration time.

Traffic Density Calculation: The traffic density is calculated based on the total count of vehicles of each class detected in the image. This provides an estimation of the overall traffic congestion at the signal.

Green Signal Time Calculation: The green signal time is determined using the traffic density and the average time for each class of vehicle to cross the intersection. This calculation ensures that the green signal time is adjusted according to the traffic conditions.

Red Signal Time Adjustment: The red signal times of other signals are adjusted accordingly to accommodate the green signal time of the current signal. This ensures a smooth transition between signals and optimal traffic flow.

Maximum and Minimum Time Limits: To prevent starvation of any particular lane, the green signal time is restricted to a maximum and minimum value. This ensures that each lane receives a fair amount of green signal time while considering the overall traffic conditions.

Signal Switching: The algorithm handles the switching of signals cyclically based on the calculated green and red signal times. Once the green timer of the current signal reaches zero, the next signal turns green for the assigned duration.

By continuously analyzing the traffic density and adjusting the signal timings based on real-time conditions, the system optimizes the traffic flow and reduces congestion at the intersection. This approach ensures efficient utilization of resources and improves the overall traffic management at the junction.

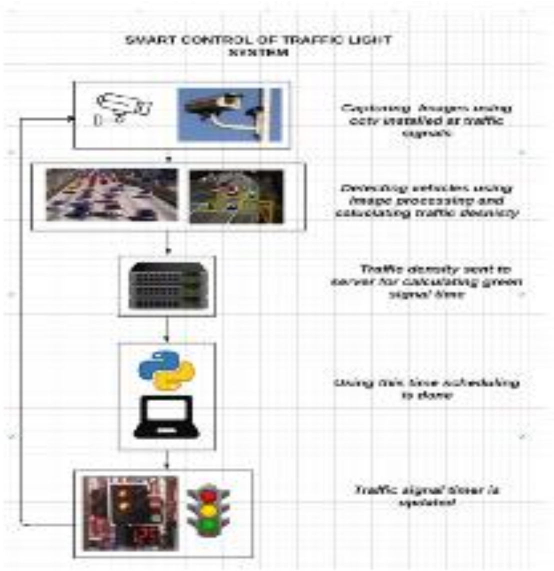

FIGURE 1

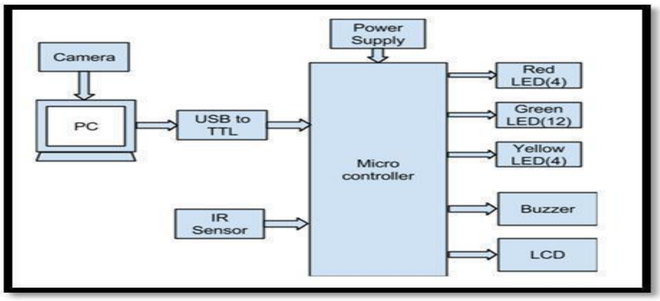

FIGURE 2

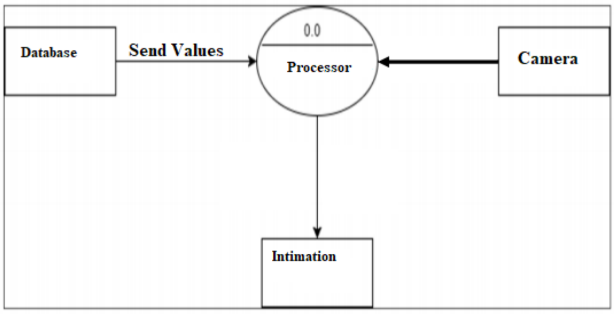

FIGURE 3

DATA FLOW

The visual representation of how data moves through an information system is called a data flow diagram. DFD can be effectively employed during analysis and is highly helpful in comprehending a system. A DFD displays how data moves through a system. It considers a system to be a process that converts inputs into desired outputs. Any complicated system won't complete this transformation in a single step; rather, the data will likely go through a number of transformations before it is output. Users can visualize how a system will work, what it will accomplish, and how it will be implemented using a data flow diagram. Old system data flow diagrams can be created and compared with a new system's data flow diagram to draw comparisons and implement a more effective system. Data flow diagrams can be used to give the user a visual representation of how the data they input will ultimately affect the system's overall structure.

DATA FLOW DIAGRAM-LEVEL 0

At the initial level, the system utilizes both a processor and an ARDUINO processor. The processor refers to the software component of the project that runs on a computer or similar device. On the other hand, the ARDUINO processor is a hardware component embedded within the traffic signal itself.

The processor, which encompasses the software part of the project, performs various tasks such as image processing, image comparison, and generating the necessary input for further analysis. These tasks are executed on a computer or similar device.

In contrast, the ARDUINO processor serves as the hardware component situated within the traffic signal. It receives the input generated by the processor and processes this information internally. Based on the input received, the ARDUINO processor allocates different time intervals to the traffic signals, thereby controlling the timing of the signal changes.

To summarize, the processor represents the software aspect of the project, executing on a computer, while the ARDUINO processor acts as the hardware component integrated within the traffic signal, receiving input from the processor and regulating the signal timings accordingly.

DATA FLOW DIAGRAM LEVEL 1

At the initial level of the system, a comparison is performed between a reference image and the captured image by the processor. The processor processes the images and generates the necessary input for further analysis. The input obtained from the processor is then transmitted to an ARDUINO processor.

The ARDUINO processor receives the input from the OpenCV processor and utilizes this information to allocate different time intervals to each signal based on the density of traffic at the junction. By analyzing the density of vehicles in the captured image, the ARDUINO processor determines the appropriate duration for each signal to optimize traffic flow.

In summary, the processor carries out the image processing and comparison tasks, while the ARDUINO processor receives the input from the OpenCV processor and assigns varying time intervals to the traffic signals based on the traffic density observed in the images.

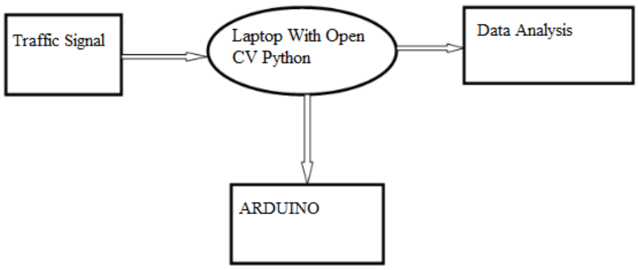

FIGURE 4

DATA FLOW DIAGRAM LEVEL 2

At the Level 2 Data Flow Diagram (DFD) of traffic monitoring, the system is further divided into subsystems to provide a more detailed understanding of its functioning. This level of the DFD incorporates additional functionalities related to traffic management and monitoring. It delves into specific components such as login, vehicle types, diversions, traffic police, length, routes, and traffic.

The Level 2 DFD also includes various image processing operations such as image resizing, RGB to gray conversion, image enhancement, and image matching. These operations are essential for processing the captured images and extracting relevant information for traffic analysis.

By breaking down the system into smaller subsystems and incorporating specific functionalities, the Level 2 DFD provides a more comprehensive and detailed overview of how the traffic monitoring system operates. It highlights the various processes and interactions involved in managing traffic,

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capturing images, and performing image processing tasks to extract meaningful insights for effective traffic management.

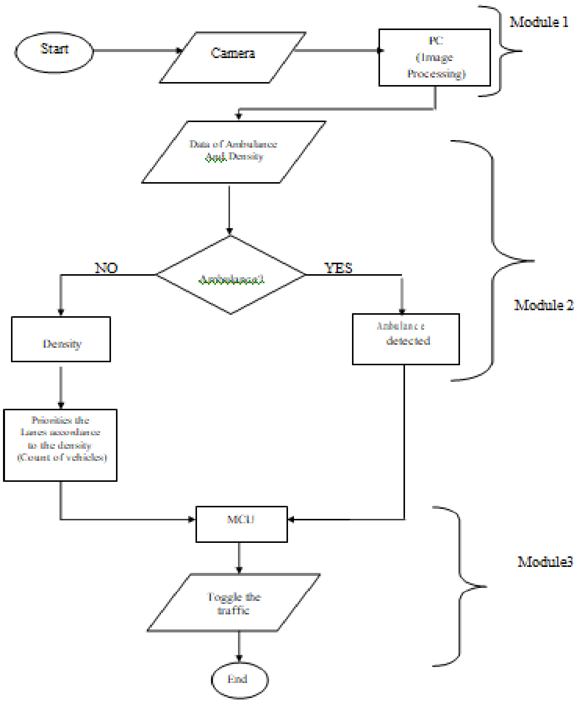

FIGURE 5

SECTION 2.4 IMPLEMENTATION

Implementation is the process of putting a plan, design, or idea into action. It involves carrying out the necessary steps to make something happen and ensuring that it is operational and usable by the intended users. In the context of the proposed system called Intelligent Traffic Control using Image Processing, implementation involves constructing the system and training users to handle and operate it effectively.

The implementation of the system involves the use of cameras placed at high posts of traffic lights to monitor the traffic scene. Images captured from these cameras are then analyzed using image processing techniques for vehicle detection and counting. Image processing proves to be an efficient and reliable method for handling various aspects of image analysis, such as compression, enhancement, and other complex operations.

In the proposed system, the captured image is compared to a reference image, and various image processing operations are applied to obtain the desired results. Image morphology techniques, such as erosion and dilation, are used for binary and grayscale images. Image scaling is also performed to adjust the density of pixels, ensuring that the system works consistently across different camera specifications.

Color perception in images is achieved through the use of cones that are sensitive to different wavelengths, such as green, red, and blue. Conversion of RGB values to grayscale is necessary to obtain a single reflected color from each pixel. Image enhancement techniques are applied to improve the quality of results.

Edge detection algorithms are employed to identify points in the image where the brightness changes sharply or there are discontinuities and noise. Different edge detection algorithms, such as Sobel, Prewitt, and Canny, are used to detect edges and differentiate between regions. Image matching, which involves comparing a reference image with the real-time image pixel by pixel, helps identify the boundaries of detected cars and generate a binary image of edge pixels. To process the data received from OpenCV Python, an Arduino is utilized. The Arduino calculates the timings and controls the switching on of traffic lights based on the density of vehicles detected. This integration of data processing between OpenCV Python and Arduino facilitates adaptive traffic signal control.

In conclusion, the implementation of the Intelligent Traffic Control system involves the construction of the system using cameras and the application of image processing techniques for vehicle detection and analysis. The integration of OpenCV Python and Arduino enables real-time data processing and adaptive traffic signal control based on the detected vehicle density.

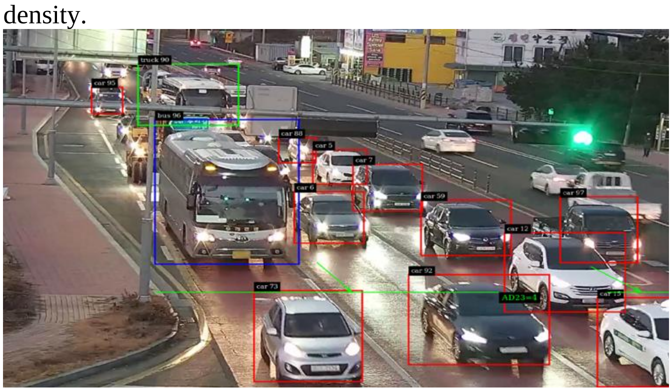

FIGURE 6

SECTION 2.5 RESULTS AND ANALYSIS

A. Evaluation of Vehicle Detection Module:

The vehicle detection module underwent testing using various test images that contained different numbers of vehicles. The accuracy of vehicle detection was found to be around 75-80%, which is considered satisfactory but not optimal. One of the main reasons for the lower accuracy is the lack of a comprehensive dataset for training the model. To improve the accuracy, it is recommended to incorporate real-life footage from traffic cameras to train the model, as this can provide a more diverse and representative dataset for better detection performance.

B. Evaluation of the Proposed Adaptive System:

To assess the performance of the proposed adaptive system in comparison to the existing static system, 15 simulations were conducted for each system, with a duration of 5 minutes per simulation. These simulations involved different traffic distributions across the four directions of the intersection. The key performance metric used was the number of vehicles that successfully passed the intersection per unit of time. Specifically, the idle time of the signal, which refers to the time when the signal is green but no vehicles pass through the intersection, was compared. This metric has a direct impact on waiting times for vehicles and queue lengths at other signals.

The traffic distributions were represented as [a, b, c, d], indicating the probability of a vehicle being present in each lane. For example, in simulation 1, the distribution was [300, 600, 800, 1000], corresponding to probabilities of 0.3, 0.3, 0.2, and 0.2 for each lane. The results of the simulations were recorded by capturing the number of vehicles that passed through each lane and calculating the total number of vehicles that successfully passed the intersection.

Further details and elaboration can be provided regarding the specific results obtained from the simulations and their implications in assessing the effectiveness of the proposed adaptive system compared to the existing static system.
The proposed adaptive system consistently outperforms the current static system across all traffic distributions. The degree of improvement in performance is influenced by the skewness of the traffic distribution among the lanes. Generally, the more skewed the distribution, the greater the performance improvement achieved by the proposed system.

When the traffic is evenly or nearly evenly distributed among the four lanes, the proposed system shows only a slight improvement compared to the current system. This is evident in simulations 1, 2, 3, and 4, where the performance enhancement is approximately 9%.

In scenarios where the traffic distribution is moderately skewed, the proposed system exhibits significant performance gains over the current system. This is observed in simulations 5, 6, 7, 8, 14, and 15, with an improvement of about 22%. These traffic distributions align more closely with real-life scenarios.

For sharply skewed traffic distributions, the proposed system demonstrates a substantial performance improvement compared to the current system. Simulations 9 and 13 showcase a distinct drop in the idle green signal time, resulting in a notable gap between the red and green lines. In these cases, the performance improvement is approximately 36%.
Furthermore, when running simulations with consistent conditions such as traffic distribution, vehicle speeds, turning probabilities, and inter-vehicle gaps for a total duration of 1 hour and 15 minutes (with each distribution lasting 5 minutes), the proposed system exhibited an average performance increase of around 23% compared to the current system with fixed times. This translates to a reduction in idle green signal time and waiting time for vehicles.

In comparison to alternative adaptive systems, the proposed system demonstrates superior performance. For instance, in reference , an accuracy of 70% is reported, while the proposed system achieves 80% accuracy. Similarly, reference shows an average performance improvement of 12% compared to static systems, whereas the proposed system achieves a higher improvement rate of 23%.

These findings highlight the effectiveness and superiority of the proposed adaptive system in optimizing traffic flow and reducing delays when compared to alternative systems and the current static approach.

3.CONCLUSION & FUTURE SCOPE

In conclusion, the proposed system for adaptive traffic signal control effectively allocates green signal time based on traffic density, leading to reduced delays, congestion, and waiting time. This results in benefits such as decreased fuel consumption and pollution. Simulation results indicate an improvement of approximately 23% compared to the current system in terms of the number of vehicles crossing the intersection, demonstrating the system's significant performance enhancement.

Further improvements can be made by calibrating the system using real-life CCTV data for training the model, which would enhance its accuracy and performance. Additionally, the proposed system offers advantages over existing intelligent traffic control systems such as Pressure Mats and Infrared Sensors. It leverages existing CCTV camera footage, requiring minimal additional hardware and reducing maintenance costs.
Expanding the project could involve incorporating functionalities such as the identification of vehicles violating traffic rules, detection of accidents or breakdowns at intersections, synchronization of traffic signals across multiple intersections, and adapting the system to prioritize emergency vehicles. These enhancements would further improve traffic management, reduce congestion, and enhance overall road safety.

Incorporating these additional functionalities and integrating the system with existing CCTV cameras in major cities would facilitate more efficient traffic management and contribute to the reduction of traffic congestion.

ACKNOWLEDGEMENT

We would like to express our heartfelt gratitude to our Head of Department Prof. Siddappaji for their continuous support and encouragement throughout the development of this research paper. Their guidance and expertise have been invaluable in shaping our understanding and implementation of the proposed system.

We would also like to extend our sincere appreciation to our guide Asst. Prof. Jeeru Dinesh Reddy and mentor Asst. Prof. K.N. Madhusudan, who provided us with valuable insights, constructive feedback, and technical expertise. Their guidance and mentorship played a crucial role in the successful completion of this paper.
Furthermore, we would like to thank the entire team involved in this project for their contributions, dedication, and cooperation. Each team member's efforts and expertise have been instrumental in achieving the desired outcomes and overcoming challenges along the way.
Lastly, we express our gratitude to all the individuals and organizations who provided us with the necessary resources, data, and information required for the research. Their support and cooperation have greatly contributed to the success of this project.
We are truly grateful for the opportunity to work on this paper and for the invaluable support received from all those involved.
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