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Density Based Traffic Management Using Deep Learning and Computer Vision

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Abstract: Our project aims to address the pressing issue of traffic congestion in cities by developing an advanced traffic control system that dynamically adjusts signal timing based on real time traffic conditions. Traditional time dependent traffic management systems often lead to inefficiencies, especially when certain lanes experience higher congestion than others. To optimize traffic flow, we have designed a framework that incorporates the density of traffic at any given moment. Our proposed solution involves utilizing the green light of a stop sign or traffic signal as an indicator for safe crossing, in addition to its usual function. This is achieved by employing cameras strategically positioned around the area to capture the number of vehicles present. The captured data is then processed by a microprocessor, such as the Raspberry Pi, which dynamically adjusts the red light timer for the corresponding lane. By incorporating real time traffic density information into the decision making process, our system ensures that green light durations are extended for lanes with higher traffic volumes, allowing for smoother traffic flow. This adaptive approach improves overall efficiency and minimizes congestion related delays. Our project aims to replace the outdated fixed traffic management systems with a more intelligent and responsive solution, ultimately enhancing the transportation experience for drivers and reducing the negative impact of traffic congestion on cities.

Keywords: *Traffic controller, Image Processing, Density based system, Raspberry Pi, Real time monitoring.*

I. INTRODUCTION

Traffic congestion has become a critical challenge faced by cities across the globe. As urban populations grow and the number of vehicles on the roads continues to increase, the need for intelligent traffic management systems becomes more pressing. Traditional time-dependent traffic control systems often prove to be inefficient, as they fail to adapt to the dynamic nature of traffic flow. To address this issue, this paper presents a novel density-based traffic management system that leverages real-time traffic data to optimize signal timing and alleviate congestion. The proposed traffic management system incorporates a comprehensive framework that considers the density of traffic at any given moment. By employing cameras stationed strategically at intersections, the system captures and analyzes the number of vehicles present in each lane. This data is then processed by a powerful microprocessor, such as the Raspberry Pi, which utilizes certain algorithms to calculate the traffic density in real-time.

Unlike conventional fixed-time traffic control systems that allocate the same green light duration to all lanes, the density-based system dynamically adjusts signal timings based on the traffic density observed in each lane. By prioritizing lanes with higher traffic volumes, the system optimizes traffic flow and minimizes congestion. This adaptive approach allows for more efficient utilization of road capacity and significantly reduces travel times for motorists. The core functionality of the density-based traffic management system lies in its ability to intelligently adjust the duration of green lights. When the system detects a higher density of vehicles in a particular lane, it extends the green light duration for that lane to facilitate the smooth movement of vehicles. Conversely, if a lane has lower traffic density, the green light duration is reduced to ensure fair distribution of green signal time across all lanes. This dynamic allocation of green light time based on traffic density leads to improved traffic flow, reduced delays, and enhanced overall transportation efficiency.

Furthermore, the density-based traffic management system offers the advantage of real-time monitoring and control. By continuously analyzing traffic density, the system can respond rapidly to fluctuations in traffic conditions, such as sudden surges in traffic volume or unexpected incidents. This real-time responsiveness allows for adaptive decision-making and ensures that signal timings align with the current traffic demands, minimizing bottlenecks and maximizing the capacity of road networks.

The implementation of a density-based traffic management system has the potential to revolutionize urban transportation. By harnessing the power of advanced technologies and intelligent algorithms, this system offers an effective solution to the problem of traffic congestion. Its ability to adapt to changing traffic patterns and optimize signal timings based on real-time data empowers cities to create more efficient and sustainable transportation networks. In conclusion, this paper introduces a density-based traffic management system that leverages real-time traffic data to dynamically adjust signal timings. By prioritizing lanes based on traffic density, the system optimizes traffic flow, reduces congestion, and enhances overall transportation efficiency. The proposed system represents a significant advancement in traffic control technology and has the potential to transform urban transportation, leading to improved mobility and a better quality of life for city dwellers.

II. RELATED WORKS

Paper [1], discusses the use of ultrasonic range sensors and servo motors in a traffic control system. The range sensors detect vehicle presence, allowing for the assessment of vehicle density in each lane, while the servo motors adjust the camera's direction to capture accurate vehicle count data. Additionally, the range sensors are utilized to detect traffic violators by sending signals of known frequency and waiting for the echo from an obstacle, enabling accurate measurement of the distance between the sensor and the object. To optimize sensor performance, a capacitor is connected in series with the power rail and ground of the range sensor to filter out noise. This noise filtering technique contributes to reliable measurement of vehicle density and detection of traffic violators. Overall, the integration of ultrasonic range sensors and servo motors in the traffic control system described in the paper offers an efficient and reliable approach to optimizing traffic flow and reducing congestion at junctions.

Paper [2], proposes a traffic control system that utilizes object identification and Haar-like features. The system includes camera equipment connected to a Raspberry Pi that captures images of traffic flow, which are then divided into four frames, one for each lane. To improve the accuracy of the system, the images undergo pre-processing to reduce unwanted noise, distortions, and features that are not relevant for further processing.

The Haar feature-based cascade classifier is used for object detection, which is a machine learning-based method that involves training a cascade function on many negative and positive images. The positive images are those that the classifier should identify, while negative images are anything except for the object of interest. In this case, the object of interest is a vehicle. Haar-like features play a crucial role in object recognition, as they consider adjacent rectangular regions of a detection window at a given location and sum up the pixel intensities in each region. The difference between these sums is then used to categorize subsections of an image. Overall, the traffic control system proposed in the paper provides a reliable and efficient approach to managing traffic flow by utilizing object identification and Haar-like features. The Haar feature-based cascade classifier is a powerful tool for detecting vehicles in traffic flow, while pre-processing ensures that the images used in the system are of the highest quality.

In **paper [3],** the focus is on image matching and number plate detection to accurately count the number of incoming vehicles in a specific lane. The authors highlight that recognition strategies based on matching a prototype sample to an unknown sample are highly effective in achieving accurate results. To implement this, the algorithm utilizes a series of vectors to calculate the distance between the unknown object and each of the prototype vectors. To enhance the accuracy of the comparison, a static or known reference image is employed. The technique that exhibits the fewest deviations from this reference photo is selected as the optimal match.

Alternatively, the paper discusses the use of photo correlation techniques, which offer a quick and convenient way to compare images. This approach involves comparing pixels pixel by pixel, enabling the application of predefined rules in mission-critical settings. While there may be some associated risks, this pixel-level comparison proves to be a more effective approach in certain scenarios. For instance, digital cameras feature a memory chip that stores captured images. These images are processed to create a matrix for each photo, and accurate comparisons between two photos require identical pixels in their respective matrices. This technique is particularly useful in matching photos and determining the identity of a vehicle.

The primary objective of the research described in the paper is to identify the registration code that corresponds to a virtual photo obtained from a camera. The proposed approach encompasses three main steps: localization of the registration code, irrespective of the license-plate length or orientation; identification of unique features within the photo; and comparison of these features against data in the registration database. Additionally, the paper discusses the segmentation of characters in the registration code and determines the popularity of each character. By applying these rules and utilizing various algorithms, it becomes more feasible to assess the individual popularity of each registration code. Consequently, this approach enables quicker determination of the popularity of each code.

In summary, the paper presents an investigation into image matching and number plate detection techniques for counting incoming vehicles in a lane. The use of recognition strategies, photo correlation, and pixel-level comparisons contribute to achieving accurate results. By implementing the proposed approach involving registration code localization, feature identification, and database comparison, it becomes easier to determine the identity and popularity of each vehicle's registration code. The findings of this research provide valuable insights into the development of efficient and reliable systems for vehicle counting and identification.

In **Paper [4],** the authors employ image processing techniques using MATLAB software, which we have also adopted in our project. In our camera system, we capture the entire top view of the four lanes and transmit the images to a PC. The received images are processed on the PC using MATLAB to determine the traffic density in each lane. This information is then sent to a microcontroller through a USB to TTL serial cable, facilitating communication between the PC and microcontroller. The received information is converted into binary form, and the traffic density is calculated based on the binary data. The microcontroller utilizes this information to control the traffic signal lights accordingly.

The image processing begins with capturing video footage from the hardware connected to the computer. The captured video is treated as an RGB image, representing true colors. The RGB image is then converted into a grayscale image, containing shades of gray and no color. To simplify subsequent image processing, various enhancement techniques are applied. Thresholding is employed to reduce the amount of information in the image, making it easier for further analysis. In this method, a threshold is defined, where pixels with higher luminosity are assigned white color, while others are assigned black. By performing thresholding, a binary image is obtained, which essentially subtracts the reference image from the captured image. In the binary image, the density of vehicles is represented by white portions, while the background remains dark. MATLAB functions are utilized to calculate the traffic density by determining the total area occupied by the white portions in the image.

In summary, by utilizing MATLAB image processing techniques, we process the captured images on a PC to analyze traffic density in each lane. The images are converted to grayscale, enhanced, and thresholded to obtain a binary representation. The resulting binary image allows us to calculate the density of vehicles by measuring the area occupied by white portions. This information is then communicated to the microcontroller for controlling the traffic signal lights based on the calculated traffic density.

Paper [5], discusses the implementation and simulation of digital image processing for traffic analysis. In this study, a traffic camera continuously captures real-time images of a junction. The Raspberry Pi 3, with its advanced capabilities, is used to apply various image processing techniques to calculate the differences between the current images and reference images.

The first step is to discard any data that is not related to colors, resulting in a grayscale image. Then, the grayscale image is converted into a binary image consisting of black and white pixels. By comparing the binary images, differences between the two images are identified. If the images are identical, the difference will be zero. However, the presence of vehicles in the junction will result in black and white pixels in the difference image, indicating where objects from one image correspond to objects from the other. To determine the traffic density, the number of black and white pixels in the difference image is compared. If there are more black pixels than white pixels, it indicates that most areas in the two images are similar, suggesting light traffic. Conversely, if there are more white pixels than black pixels, it implies that there are more differences in one image compared to the other, indicating heavier traffic in that area. Since these differences are relative to the location of vehicles on the screen, traffic density can be estimated accordingly.

The information about traffic density is then uploaded to an M2x IoT cloud server hardware, which is connected to the internet via Wi-Fi. A desktop Java application is designed to monitor and control traffic lights, allowing access to the information stored in the cloud server. Commands uploaded to the cloud platform are collected by the application and sent to an embedded system connected via Raspberry Pi 3, which controls the timing of the traffic signals. To create a simulation in the project, several steps were followed. A Java-based user interface (UI) application was developed to connect to the server's data. The image processing was simulated using MATLAB to calculate traffic density. The control of GPIO (General Purpose Input/Output) pins was performed using Raspberry Pi 3. Real-time images were captured using Raspberry Pi 3, and the captured images were processed to calculate traffic density. Data was exchanged between the Raspberry Pi 3 and the server to ensure synchronization.

Overall, the paper presents a comprehensive approach for traffic analysis using digital image processing techniques. By utilizing the Raspberry Pi 3 and cloud-based infrastructure, real-time traffic density information can be obtained and used for effective traffic control.

III. PROPOSED BLOCK DIAGRAM

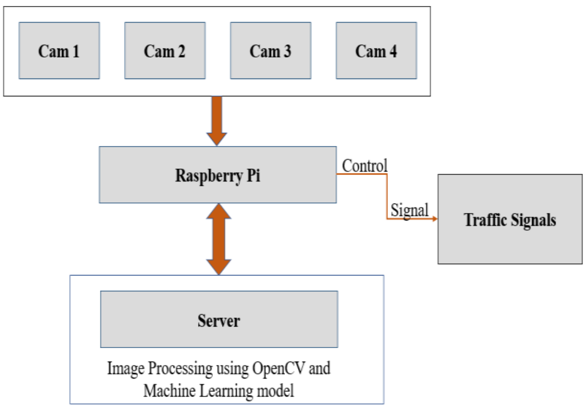

Fig 1. Block Diagram

IV. METHODOLOGY

1. Sensor Deployment: Install sensors at strategic locations, such as junctions or intersections, to capture real-time data on traffic flow. Various types of sensors can be used, such as ultrasonic sensors, range sensors, or video cameras. These sensors should be able to detect the presence of vehicles and measure traffic density accurately.
2. Data Collection: The sensors continuously collect data on vehicle presence and density in each lane or area of interest. This data is typically captured in the form of images, video footage, or raw sensor readings.
3. Image Processing: If images or video footage are collected, image processing techniques are applied to extract relevant information. This may involve converting the images to grayscale, applying filters or image enhancement techniques to improve image quality, and segmenting the images into distinct regions or lanes.
4. Vehicle Detection and Tracking: Using computer vision algorithms, the system identifies and tracks vehicles within the captured images or video footage. This can involve techniques such as object detection, pattern recognition, or machine learning-based approaches.

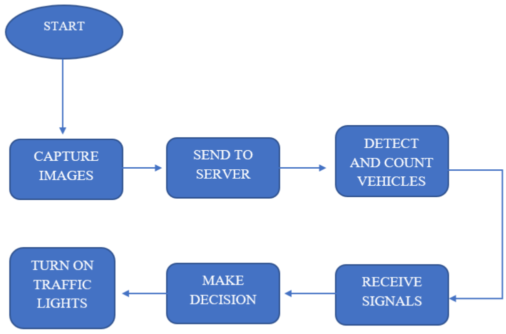

Fig 2. Methodology

5. Density Calculation: Once vehicles are detected and tracked, the system calculates the density of vehicles in each lane or area. This can be done by counting the number of vehicles in a specific region or by estimating the occupied area of vehicles within a given lane.
6. Data Analysis: The collected data is analyzed to determine the congestion level and traffic conditions in real-time. This analysis may involve comparing traffic densities across different lanes, identifying congested areas, or detecting traffic anomalies.
7. Decision-Making and Control: Based on the analyzed data, the traffic management system makes decisions on adjusting signal timings or implementing traffic control measures. This can be done using algorithms that optimize signal timings based on traffic density, prioritize certain lanes or directions, or dynamically adapt to changing traffic conditions.
8. Communication and Control: The system communicates the control commands to the traffic signal controllers or other relevant infrastructure. This can be done through wired or wireless communication protocols, such as Ethernet, Wi-Fi, or cellular networks. The control commands adjust signal timings, synchronize traffic signals, or implement other traffic management strategies.
9. Feedback and Iteration: The system continuously monitors the effectiveness of its decisions and control actions. Feedback from the traffic flow, sensors, or other monitoring systems is used to evaluate the impact of the implemented measures. Based on this feedback, the system can refine its control strategies and make adjustments to improve traffic management efficiency.

V. RESULTS AND DISCUSSION

Table 1. Component testing

Hardware/Component	Activity	Result
Camera	Capture the Images	Pass
Raspberry Pi	Send the Captured Images	Pass
Server	Receive the Captured Images	Pass
Server	Detect The Vehicles	Pass
Server	Send Back the Count	Pass
Raspberry Pi	Receive Vehicle Count	Pass
Raspberry Pi	Send Traffic Signals	Pass

Table 2. All lanes empty (Case1)

Test case	Making Decision
Input	Images of all four lanes
Expected Output	• Give Count as zero • Keep Capturing images
Actual Output	• Give Count as zero • Keep Capturing images
Status	pass

Table 3. Equal Numbers of vehicles in two or more Lanes (Case2)

Test case	Making Decision
Input	Current Cycle- Lane 1: 3 Vehicles, Lane 2: 3 Vehicles Previous Cycle-Lane 1: 2 vehicles, lane 2: 0 vehicles
Expected Output	Free Lane 1, Also remove it
Actual Output	Freed Lane 1, No lane 1 found in current cycle
Status	Pass

Table 4. General Case (Case3)

Test case	Making Decision
Input	Lane 1: 4 Lane 2: 1 Lane 3: 6 Lane 4: 3
Expected Output	Free Lane 3 Remaining Lanes: Lane 1, Lane 2, Lane 4
Actual Output	Freed Lane 3, Also Removed from The Cycle.
Status	Pass

Code Outputs for individual cases of traffic pattern:

```
{'lane1': 8, 'lane2': 7, 'lane3': 6, 'lane4': 1}
[1, 6, 7, 8]
lane1  is freed!
enter new value for  lane2
None
```

Output 1. When Lane 1 has more Density

```
{'lane1': 3, 'lane2': 7, 'lane3': 6, 'lane4': 1}
[1, 3, 6, 7]
lane2  is freed!
enter new value for  lane1
None
```

Output 2. When Lane 2 has More Density

```
{'lane1': 3, 'lane2': 4, 'lane3': 6, 'lane4': 1}
[1, 3, 4, 6]
lane3  is freed!
enter new value for  lane1
None
```

Output 3. When Lane 3 has more Density

```
{'lane1': 6, 'lane2': 5, 'lane3': 2, 'lane4': 8}
[2, 5, 6, 8]
lane4  is freed!
enter new value for  lane1
None
```

Output 4. When Lane 4 has more density

```
{'lane1': 1, 'lane2': 5, 'lane3': 5, 'lane4': 0}
[0, 1, 5, 5]
lane3  is freed!
enter new value for  lane1
None
```

Output 5. When two Lanes have same density

```
{'lane1': 0, 'lane2': 0, 'lane3': 0, 'lane4': 0}
[0, 0, 0, 0]
Two or more lanes are empty!
```

Output 6. When two or more lanes are empty

CONCLUSION

With the escalating issue of traffic congestion in urban areas, a novel traffic management system has been proposed to address the problem. The core concept of this system revolves around capturing images using cameras strategically positioned at key locations. These images are then analyzed to identify areas of high traffic density, enabling the system to trigger traffic movements accordingly. By dynamically adjusting the operation of traffic lights based on real-time image data, the proposed system aims to reduce waiting times and enhance overall traffic flow. The system functions autonomously, continuously collecting and processing images in real-time from various lanes. This real-time data enables the system to make dynamic decisions, optimizing traffic signal timings and minimizing the likelihood of traffic congestion at intersections. In addition to cameras, the integration of multiple sensors, such as ultrasonic sensors, further enhances the system's capabilities. These sensors detect emergency vehicles approaching the intersection, allowing the system to prioritize their passage and facilitate smooth traffic flow.

Implementing this traffic management system offers significant advantages over traditional timed traffic signals. It enables better utilization of road infrastructure, reduces congestion, and improves overall efficiency. Moreover, the proposed system allows for future enhancements and customization. For instance, additional features like incident detection and notification could be incorporated, along with integrating other devices such as traffic violation monitoring systems and city surveillance cameras. This would provide enhanced control, monitoring, and enforcement capabilities for city streets and traffic regulations.

In summary, the proposed image-based traffic management system offers a promising solution to the growing problem of traffic congestion. By leveraging real-time image data and dynamic decision-making, it has the potential to significantly improve traffic flow, reduce waiting times, and pave the way for future enhancements and customization to meet the specific needs of urban areas.

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