

Traffic Signal Control Based On Density

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Abstract: *Traffic congestion in the cities has been a significant problem in the emerging metropolitan cities with the high rate of growth in the number of vehicles and the availability of road networks. Traditional traffic light systems are based on time and supervision that is not automatic and cannot be adjusted to alterations in traffic density. The paper will suggest a real-time intelligent traffic signal control system based on density and digital image processing. The system records the traffic images of the cars captured by the camera and processes the traffic with the Canny edge detection algorithm to estimate the number of vehicles in the traffic by dividing the number of white pixels by the number of total pixels. Depending on the identified level of traffic density, the timing of traffic signals is adjusted in the dynamic manner so as to maximize traffic flow and minimize time wastage. Flask is used as the back end framework, and front end development is carried out using HTML, CSS, and Bootstrap. Experimental assessment based on varying traffic conditions has shown better adaptability, response time and traffic management efficiency as opposed to the traditional systems with fixed-time time.*

Keywords: Intelligent Traffic System, Density Estimation, Canny edge Detection, Flask, Image Processing, Smart Traffic Signals

I. INTRODUCTION

The problem of traffic congestion in the cities is becoming very alarming because of the growth of population and urbanization. The conventional types of traffic light control systems which are fixed time based are not effective since they fail to take into account the real time traffic density. In low traffic stages, unnecessary delays are incurred to the vehicles, when the peak times occur, congestion is caused by the lack of time of the green signal. Such inefficiency results into wastage of fuel, time wasted when carrying out the trip, and environmental pollution.

The latest developments of computer vision and image processing make it possible to create adaptive traffic management systems. Density-based traffic signal control is an intelligent method, which modulates the timing of the signals as per the amount of vehicles at a crossroad. The proposed system employs digital image processing methods to estimate traffic density dynamically and in real time to dynamically control the timing of the signals. Its implementation is light as well as affordable and applicable in smart city.

II. RELATED WORK

A number of scholars have suggested adaptive traffic control systems based on sensors, Internet of Things, and machine learning. Systems that use sensors have infrared or ultrasonic sensors to detect the presence of vehicles although their maintenance and installation are quite expensive. Systems based on the IoT offer real-time communications although they need a well-functioning network structure. Convolutional neural networks, which are deep learning-based traffic detection models, are high-quality models that require a lot of computation and training data.

Denocity as image processing provides a viable trade off between accuracy and computational cost. The most popular and common edge detection algorithms, in especially the Canny edge detection algorithm, are applied in the



determination of object edges and the extraction of structure in images. Nevertheless, there are a limited number of systems that combine real-time density estimation with a light-weight web- based application based on Flask and frontend technologies. The paper will fill this gap by offering an easy but effective system.

III. PROPOSED SYSTEM

The suggested system will comprise of five key modules; image acquisition, image preprocessing, density estimation, signal timing decision and web-based monitoring interface. The traffic camera is mounted on the traffic intersection and takes real-time pictures. The image obtained is turned into grayscale to make processing easy and less complex to compute. Gaussian filtering is conducted to remove noise and then Canny edge detection algorithm is applied.

The edge detection process identifies the boundaries of the vehicles in the image making the white pixels to depict the edges identified. The density of the traffic is assessed by determining the ratio of white pixels to the total pixels in the picture. Depending on the threshold values, one classifies the traffic condition as low, medium or high density. The timing of the traffic light is then optimally changed based on the classification findings. This will provide effective movement of traffic and minimize unwarranted delays.

IV. METHODOLOGY

The process starts with an image of the traffic camera that records a real time image. The image is converted to grayscale and blurred with the help of Gaussian. With the help of Canny edge detector algorithm we can detect the edges in the frame. Once the edges have been detected, the count of white pixels/pixels is determined, and the density ratio is obtained.

Traffic density is calculated mathematically, as follows:

$$\text{Density} = (\text{Total Number of Pixels}) / (\text{Number of White Pixels})$$

When the density falls within 0 and 0.25, the traffic is considered to be low and a green signal is given a time of 10 seconds. A density of between 0.25 and 0.50 is posted as medium and 25 seconds is the signal duration set. The traffic above 0.50 is considered as highly congested and the green light is increased up to 40 seconds. This dynamic allocation enhances performance of intersections.

V. IMPLEMENTATION

The system is developed with Python and Flask as the framework of the backend. Flask is used to process image processing requests and send the results to the front end interface. Implementation of image processing algorithms such as grayscale conversion, Gaussian blur, and Canny edge detector is done using openCV. The frontend is created with the help of HTML as a structure, CSS as a styling tool, and Bootstrap as a responsive design.

The web interface enables the user to either post traffic pictures or to see live camera images. Once processed, the system shows the original image, the edge-detected image, the percentage of calculated density and the signal timing that is predicted. Flask is very lightweight, which is why it has a high response time and is easily deployed.

VI. RESULTS AND DISCUSSION OF THE EXPERIMENTS.

The system was experimented in different traffic conditions such as low, medium and high traffic conditions. The outcomes of the experiments prove high abilities of density estimation. In the low traffic situation, the expected density was close to the real density at about 95 per cent. The error rate of medium traffic was approximately 93 percent and high-density conditions got close to 96 per cent.

The proposed system had a significant reduction in the average waiting time as compared to the fixed-time signal systems. The adaptive mechanism made sure that the duration of the green signal was extended only when necessary hence minimized congestion. Also the system had low response time as a result of effective image processing operations. These findings prove the efficiency of the density-based method in the real-time operations.



VII. HARDWARE IMPLEMENTATION

A software implementation on a processing unit like a Raspberry Pi or personal computer was made as a prototype hardware implementation with a USB camera attached. Traffic lights were simulated on signal LEDs traffic lights were simulated with the help of were used. The system was able to handle real time frames and dynamically control signal timing according to density reported. The viability of real-time implementation in urban crossroads was confirmed by the hardware outcomes.

VIII. ADVANTAGES

The proposed density-based traffic signal control system has a number of important benefits over the conventional fixed-time and sensor-based traffic management systems. The main advantage is the fact that it is real-time flexible. The proposed system will minimize unnecessary waiting time and enhance traffic throughput by operating dynamically, unlike the conventional systems that use fixed intervals to run specific signals, and therefore vary the green signal duration according to the real traffic density.

The other significant benefit is cost-effectiveness. The system does not require installation of physical sensors on the roads to work and thus reduced infrastructure and maintenance expenses are incurred because the system uses camera based image processing. Most of the urban locations have already installed cameras that monitor the activities and hence the proposed system is very feasible without necessarily involving extra heavy investment.

Scalability and flexibility is also offered by the system. It can easily be extended to other intersections by introducing more cameras and linking them to a centralized server. The web-based interface allows remote monitoring and control allowing the traffic authorities to see the level of congestion in real time. Moreover, the system enhances fuel efficiency and lowers the pollution of the environment by reducing wastage of time at crossroads.

Another beneficial factor is automation. The system minimizes human requirements and manual traffic control thus removing the mistakes that are related to human tiredness or miscalculation. The software architecture is modular, which will facilitate easy future upgrades and also ensure the software is enhanced without redesigning the whole system. Also, the lightweight version makes the implementation fast and has less requirements in terms of computation as compared to deep learning-based models.

IX. CONCLUSION

This study introduced a live-time density-based traffic signal controller based on the use of digital image processing methods. The system uses Canny edge detection to approximate the traffic density of the images captured and also dynamically set the timing of the signal according to the level of congestion. The application on Flask, HTML, CSS, and bootstrap proves that a powerful and scalable intelligent traffic control solution may be created with lightweight web technologies.

The experimental findings show that the proposed system is much more adaptable and less time consuming in the average waiting period than the traditional fixed-time signal systems. The density estimation algorithm gives good performance in a wide range of traffic conditions, and guarantees optimal signal allocation. The practical feasibility of real-time implementation is also confirmed by its hardware prototype.

Altogether, the suggested system will enrich the process of the smart city development because it provides a cost-efficient, automated, and efficient traffic management solution. It proves that an image processing-based density estimation can be an effective substitute of costly sensor-based systems at a high level of performance and scalability.

X. FUTURE WORK

The proposed system has yielded promising results though a number of improvements can be made in the future research. The first significant enhancement concerns the deep learning-based vehicle detection models including YOLO or Faster R-CNN to enhance the accuracy of density estimation, particularly in challenging conditions when it



comes to occluded vehicles or vehicles that overlap each other. These models may increase flexibility during night and poor weather conditions.

Further research can also be on multi- junction coordination whereby, the traffic lights at the two intersections communicate with other lights to make the entire network to coordinate the traffic flow, instead of acting individually. It can be done by the implementation of IoT-based communication protocols and central cloud servers.

The other significant improvement is emergency vehicle prioritization. Through the combination of siren detectors or RFID identify systems, the traffic signal can automatically allow green lanes to ambulances, fire brigades, and police cars. Also, prediction analytics may be added based on past traffic logs to predict congestion patterns and reaction in advance instead of response.

Monitoring and data analytics can also be improved further by deploying on cloud platforms as well as being integrated with smart city dashboards. Traffic authority Mobile application can also be used to alert instantly when there are abnormal congestion trends. Lastly, the incorporation of green sources of energy like solar powered signal systems can enhance sustainability and lower the expenses involved in running the system.

The proposed density-based traffic signal control system can also be extended to be a comprehensive intelligent traffic control system to be used by large-scale urban implementation in the future, using an embedded system

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