

IoT-Enabled Traffic Violation Detection and Dynamic signal control using image Processing

Jadhav Prafulla Balshiram¹, Dr. Manish Saraf²

¹Research Scholar, Department of Computer Science, Eklavya University, Damoh, M.P

²Supervisor, Department of Computer Science, Eklavya University, Damoh, M.P

ABSTRACT

Problems with traffic management, road safety, and rule enforcement have arisen as a result of the exponential increase in vehicle traffic in metropolitan areas. Accidents, delays, infractions, and congestion are common results of the inefficiency of human monitoring methods and traditional traffic signal systems. In light of these difficulties, this research suggests a framework for traffic infraction detection and dynamic signal regulation that makes use of image processing methods and is enabled by the Internet of Things (IoT). In order to continually gather real-time traffic data, the system incorporates Internet of Things (IoT) devices including sensors, security cameras, and communication modules. Autonomous Number Plate Recognition (ANPR) guarantees precise identification of infraction cars, while image processing and computer vision algorithms catch infractions such lane indiscipline, overspeeding, and red-light jumping. Congestion is minimized and traffic flows smoothly thanks to dynamic signal management methods that optimize signal timing based on real-time data on traffic density. The efficiency, effectiveness, reduction of emissions, and assistance for emergency mobility are all improved by this dual strategy, which also improves traffic law enforcement. The information gathered is also helpful for smart city planning and urban traffic management in the future. By combining safety enforcement with dynamic mobility optimization, the suggested system proves to be an intelligent, scalable, and adaptable solution for contemporary traffic management.

Keywords: Image Processing, Real-time Monitoring, Computer Vision, Adaptive Traffic Management, Vehicle Detection.

INTRODUCTION

On a global scale, traffic management systems are facing formidable problems due to the exponential increase in both the number of cars and metropolitan areas. Traditional methods of traffic management, which depend on static monitoring and pre-programmed signal cycles, often fall short of keeping up with the ever-changing demands of contemporary urban areas. Congestion, infractions of traffic rules, delays in emergency services, pollution, and road accidents are all outcomes of this. Intelligent, adaptable, and efficient systems that react to real-time circumstances are now within reach, thanks to advancements in image processing and the Internet of Things (IoT). A long-term answer to the problems of traffic congestion, inefficiency, and safety may be found in a framework that detects traffic violations and uses the Internet of Things (IoT) to manage the signals. Conventional traffic control relies heavily on predetermined signal timings and human involvement. When it comes to dealing with unexpected congestion or infractions like red-light jumping, overspeeding, or lane shifting, these methods are ineffective and don't adapt well to different traffic volumes. Delays in penalty enforcement and poor monitoring are also caused by the lack of automation in real-time infraction detection. With the help of the Internet of Things (IoT), a network of interconnected devices and sensors may gather, analyze, and broadcast data on traffic, while image processing allows for precise identification of infractions based on camera inputs. By combining these technologies, we can build an adaptive traffic control system that is both smart and safe.

Installed at intersections, highways, and urban roadways, networked cameras, sensors, and communication modules form the backbone of traffic systems that are enabled by the Internet of Things. Data like as vehicle density, speed, and movement patterns are captured in real-time by these sensors and sent to computers in the cloud or on the edge for analysis. Next, real-time traffic offenses are identified using image processing methods including object identification, motion tracking, and pattern recognition. Intelligent algorithms powered by computer vision and machine learning can identify instances of red-light running, excessive speeding, lane discipline infractions, and illegal entrance into prohibited zones. The system ensures accountability and deterrent by recording infractions and transmitting them to the appropriate authorities for punishment processing. Internet of Things (IoT) smart traffic management also includes dynamic signal control. In contrast to static systems, dynamic control optimizes signal cycles based on real-time data

on traffic density and flow patterns. It is possible, for instance, to lengthen the green signal time on more populated routes and shorten it on less populated ones. This improves traffic flow, decreases fuel use, and eliminates needless waiting periods. Improved urban transportation network efficiency is the result of a system that can constantly learn and adapt thanks to the Internet of Things (IoT) sensors coupled with adaptive signal regulation.

Automating violation detection is a major benefit of combining IoT with image processing as it decreases reliance on humans and mistake rates. With the use of Internet of Things (IoT) sensors and Automated Number Plate Recognition (ANPR) devices, information on violating cars may be recorded and stored in real-time. The result is an open and unchangeable method for enforcing traffic laws. In addition, authorities can respond swiftly to incidents involving accidents, emergency vehicle movements, or criminal activity on highways thanks to real-time surveillance. When it comes to long-term traffic planning, the data gathered from IoT-enabled devices is invaluable for detecting high-risk zones, peak traffic hours, and accident-prone places. The larger goal of smart cities is to maximize resources and enhance quality of life via the deployment of digital technology; this includes traffic management through the Internet of Things and image processing. Smart city planning can cut down on pollution from idle cars, make transportation more efficient, and make roads safer for everyone. Further, by integrating with cloud platforms, urban planners and lawmakers may save historical data, use predictive analytics, and get decision-making help. These systems have the potential to develop into self-learning entities that adapt their detection and control tactics in response to patterns and feedback via the use of machine learning and artificial intelligence (AI).

Problems with installing and maintaining IoT-enabled traffic control systems, worries about data privacy, and the need of strong network connection are some of the obstacles to their widespread use. Since transportation infrastructure is essential to the operation of cities, it is also crucial to provide system resilience against cyber attacks. The long-term advantages of less congestion, better safety, and environmental sustainability far exceed the constraints, notwithstanding these problems. All things considered, dynamic signal control provided by image processing and the Internet of Things is a huge improvement over the old ways of detecting traffic violations. Such systems are able to build sustainable, efficient, and safe urban transportation networks because they combine adaptive decision-making with sophisticated picture analysis and real-time data collecting. The proper management of traffic will become more dependent on the use of these technologies as urban areas expand.

LITERATURE REVIEW

Parate, Mr. (2024) This research introduces a new approach to managing traffic in metropolitan areas by combining image processing, the internet of things (IoT), and automated street lighting. Smart cameras placed at key junctions provide continuous real-time traffic data, including vehicle counts and congestion levels. With this information, a centralized control unit may adjust the timing of traffic signals using complex algorithms. Furthermore, an automated street lighting system enhances sustainability by including sensors that detect nearby vehicles and people. By allowing users to adjust the brightness of the lights as required, this technology maximizes energy efficiency and helps save costs. By reducing traffic and encouraging environmentally responsible city planning, this smart traffic management system built on the Internet of Things (IoT) generally makes everyone's lives easier and safer.

Bhavana, Pendurthy et al., (2023) many cities in India and throughout the world suffer from traffic jams caused by cars. Constant gridlock is having a negative impact on people's time, energy, and health due to broken traffic signals and other problems. Because of this, finding a solution to the traffic congestion issue is crucial. This article proposes a traffic management system prototype that makes use of infrared sensors, an Arduino, a serial connection to a parallel shift register, and LED displays. Placing the infrared sensors at the four-lane intersection after a certain distance allows one to estimate the traffic density. Both the timing and the order of the green lights may be adjusted in real time using the data acquired from the sensors. The proteus software is used to implement the planned road traffic management system. A shorter green light delay is used in low density zones, whereas a longer one is applied in heavy traffic zones. Additionally, the system is meant to prioritize lanes with few or no cars by minimizing delays at the green light.

Chaus, Nahida et al., (2022) This research introduces a method for traffic analysis that alerts traffic control via the use of Image Processing. We are able to recognize automobiles in this framework utilizing pictures and the Python programming language, rather than relying on sensors. After digital media images are fed into an image processing algorithm, the algorithm uses open cv libraries to identify vehicles in the images. The final tally of detected vehicles is based on the vehicle count, and the time is adjusted accordingly to reduce road traffic congestion. The three issues plaguing the traffic system have their solutions in this scheme. Regardless of the density conditions, the primary issue is the predetermined timings for each traffic light. To do this, we adjusted the times of the signals. The basic idea is to use image processing to estimate the density on each lane of a four-lane intersection from a distance of fifty meters. Once you've tallied all of the vehicles, activate the green light for a certain amount of time to further investigate the vehicle count ratio. The goal is to empty the most heavily populated lane of traffic before proceeding to the next available lane in a clockwise fashion. For denser media, the signal time is fine-tuned to the millisecond.

Subramani, Neelakandan et al., (2021) With the population on the rise and traffic density staying the same, traffic forecast is more difficult than ever before. More communication in cars means more time and gas wasted, more pollution, and maybe even more people killed when they get stuck in traffic. Congestion prediction and control systems are a very small field of study, which means they may not be as accurate. Consequently, this study suggested a smart city traffic light management system based on the Intel 80,286 CPU and an efficient Internet of Things (IoT) traffic prediction system utilizing the OWENN algorithm. Gathering Internet of Things (IoT) data, extracting features, classifying data, optimizing traffic IoT values, and controlling traffic signals are the five stages that make up the suggested system. The first step is to get the dataset's IoT traffic data. Afterwards, characteristics such as traffic, weather, and directions are retrieved and fed into the OWENN classifier, which then determines the location with the highest volume of traffic. If traffic is heavier in one way than the other, the system will optimize the IoT values using IBSO and then use an Intel 80,286 CPU to govern the flow of traffic. A smart city application that makes use of an Intel 80,286 CPU and the OWENN algorithm to regulate traffic signals and estimate traffic volumes. This stage involves doing the classification once the characteristics have been extracted. The optimal weight Elman neural network (OWENN) technique is used to classify the locations with the most traffic here. OWENN outperforms the state-of-the-art models with an accuracy of 98.23% and an F-score of 96.69%. Outcomes from experiments demonstrate that the suggested methodology achieves better outcomes than the current best practices.

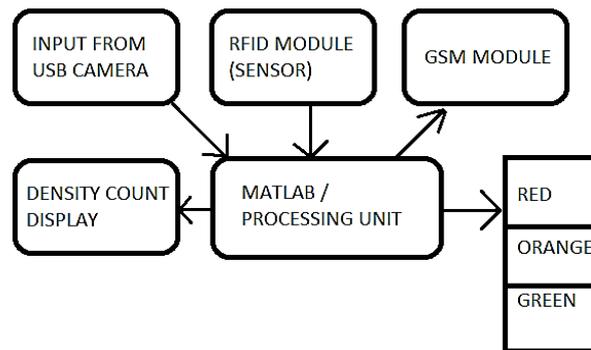
M N, Vimal et al., (2020) With the advent of new technology, data has become an integral part of almost every industry. Workers at the hub are still manually controlling the signals, even though there have been enormous breakthroughs. Traffic congestion is a common problem, particularly in downtown regions. This paper presents an Internet of Things (IoT) based traffic management system to improve traffic-related issues, assist ambulance drivers in determining the status of signals and selecting a route where traffic flow can be controlled remotely and where traffic violations can be identified and handled by on-site traffic officers. Based on the ideas of the Internet of Things, it shows a framework with a few sensors interfaced with node MCUs, such as an infrared sensor and an RFID reader. Using it, regular cities may become "smart cities" that make use of information and communication technologies. When it comes to automating processes, the Internet of Things concept may be crucial. In order to ensure that cars may travel freely, a method for gauging traffic density is also taken into account. Any major city may more easily adopt the suggested plan since it is more generic.

Sakhare, Nitin et al., (2020) The traffic management issue has grown substantially as the number of cars on the road has increased. The efficiency of the manual traffic system is low. The article introduces an IoT and image processing-based adaptive traffic management system. The suggested system can use image processing to examine data in real-time. The use of cameras allows for the continuous monitoring of several lanes. We look at the data from all the lanes. To determine how many cars are in each lane, image processing is used. The central processing unit receives the lane counts. The algorithm determines the waiting time for each lane based on the number of cars, and then the signal lights are set. The technique streamlines traffic clearing and decreases the average waiting time. As an adaptive traffic management system that makes use of the Internet of Things (IoT), it lessens pollution caused by CO₂ emissions and is helpful in emergency circumstances.

S, Aakash & M N, Vimal. (2020) with the advent of new technology, data has become an integral part of almost every industry. Workers at the hub are still manually controlling the signals, even though there have been enormous breakthroughs. Traffic congestion is a common problem, particularly in downtown regions. This paper presents an Internet of Things (IoT) based traffic management system to improve traffic-related issues, assist ambulance drivers in determining the status of signals and selecting a route where traffic flow can be controlled remotely and where traffic violations can be identified and handled by on-site traffic officers. Based on the ideas of the Internet of Things, it shows a framework with a few sensors interfaced with node MCUs, such as an infrared sensor and an RFID reader. Using it, regular cities may become "smart cities" that make use of information and communication technologies. When it comes to automating processes, the Internet of Things concept may be crucial. In order to ensure that cars may travel freely, a method for gauging the density of traffic is also taken into account. Any major city may more easily adopt the suggested plan since it is more generic.

RESEARCH METHODOLOGY

Two primary sections make up the project. In the first section, we calculate the road density count and deal with the ongoing video surveillance of the cars. We modify the signal durations after we acquire the density count. The second section addresses the issue of the traffic signal being disregarded. If the signal is interrupted, the GSM module detects the vehicle's RFID tag and sends a penalty message based on that information. This is a simplified version of the working block diagram.



As may be seen from the block diagram The central processing unit receives data from the USB camera. After the photos are processed by the processing unit or MATLAB, the density count is calculated and shown via a graphical user interface. The length of the green and red lights is now adjusted based on the density count.

In continuation of Part 2, the processing unit activates the GSM module to submit the necessary complaint if it receives an affirmative signal from the RFID sensors indicating that a traffic signal-breaking RFID tag has been detected.

There are four sections to the processing job. The first step is to use MATLAB to analyze the live video feed and capture snapshots from the stationary camera. In the second section, a value of 500 is taken as a threshold after processing the collected snapshot. Object detection, which is accomplished by improving picture characteristics, is the third step. The penultimate step is density counting, which involves tallying all of the cars. What follows is a schematic of the proposed system at its most basic level.

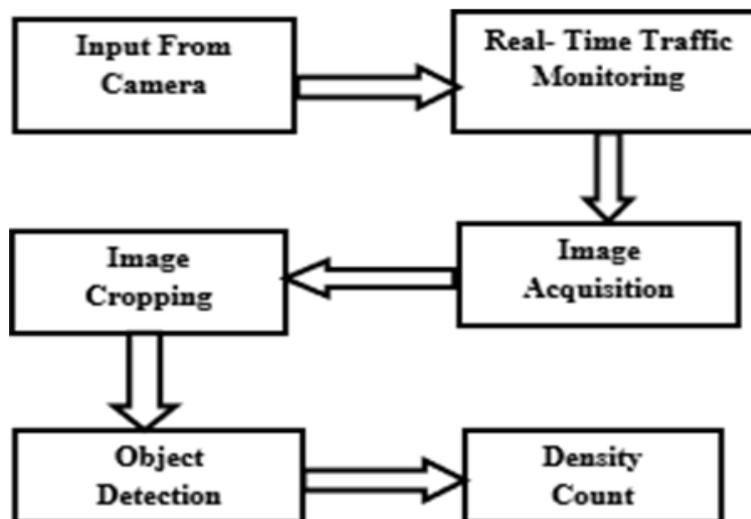


Figure 1: Block Diagram of the Proposed Model

Processing of Video Signal and Image Acquisition

Keeping a constant eye on the road via video surveillance is the first step in extracting raw data. The MATLAB program is used to process the live video. The traffic light pole or the top of the light would be the ideal locations for the USB camera. Taking continuous video footage is the next step. The next step is to convert the photos from RGB to grayscale. By comparing it to the previous picture of the empty road, a threshold value may be determined. When the road is clear, the reference picture is taken from the live video and shown in Fig. 2(a). How to choose the area of interest including the cars is detailed in the section that follows.

Image Cropping

Step two involves using MATLAB to create picture cropping algorithms and then selecting the desired region. By removing extraneous backdrop data, cropping makes it possible to see only the area of the road where the cars are. Since the camera remains still during the live broadcast, this superfluous data is preserved in every frame. Figure 2(a), which does not include any road traffic, was used as a reference picture to crop the necessary region. Fig. 2(b) shows the process of creating a binary picture with the same dimensions as the reference image. Then, the road area is colored white and the residual region is shaded black. As shown in Figure 2 (c), the final target area is obtained by multiplying the reference picture with the cropped black and white image. The process of object detection is detailed in the section that follows.

Traffic Density

Finding out how many vehicles are using the designated route is the next stage. The cars are identified and then tallied in order to ascertain the traffic density.



Figure 2: (a) Reference Image taken from the Live Video



Figure 2: (b) Defining the region of interest



Figure 2: (c) Selection of the target area

Object Detection

Fig. 2(c) shows the targeted region, and the third phase is object or vehicle detection to identify and count the cars there.

As shown in Figure 3(a), the initial step in doing object recognition is extracting the frame from the real-time video sequence. After that, we'll turn the reference picture and the real-time image into grayscale. After that, we'll find the absolute difference between the two photos. The difference picture just shows the presence of automobiles in the specified region since the road dimensions remain constant. Figure 3(b) shows the difference image.



Figure 3: (a) Real-time image extracted from the live video

Although the cars are visible in Fig. 3(b) inside the target region, their visibility is not much improved there. By applying a threshold value to the difference picture, we may transform it into a binary image that better displays the cars.



Figure 3: (b) Difference of reference and real time image

Figure 4(a) shows the final binary picture, which greatly enhances the visibility of any item. Multiplying the clipped picture (Fig. 2(b)) with the improved version of the difference image (Fig. 4(a)) allows us to identify just the cars in the required region. Figure 4(b) shows the product picture. Figure 4(b) eliminates extraneous data and displays just the locations of cars in the selected region.



Figure 4: (a) Binarization of the Difference Image



Figure 4: (b) Image Highlighting the Presence of Vehicles in the Targeted Area

A collection of linked pixels is sought for by the algorithm. There is a minimal need that must be met before a linked area may be regarded as a vehicle. On the other hand, the aforementioned criteria may be able to identify more than one area of a vehicle. To get around this issue, we may identify the overlapping bounding boxes of the chosen areas and filter out the smaller, more overlapping ones. The traffic signal length is adjusted and the light delay is designed using MATLAB based on the density count.

RESULTS AND DISCUSSIONS

This study use image processing techniques to determine the traffic density in one direction of the road in an effort to alleviate traffic congestion. In the first step of the system, known as image acquisition, a stationary camera affixed to any pole processes live footage. Afterwards, the live video is incrementally processed one frame at a time by transforming each frame into grayscale. The reference image is a picture of a road that is completely deserted when there is no vehicular activity. Step two involves cropping the photograph to just show the parts of the scene where the automobiles are, eliminating any extraneous elements. Taking the absolute difference of each extracted frame with the reference picture, the next step finds objects in live video. After that, binarization of the difference picture makes things stand out more. Finally, by tallying up all the cars in the designated target area, you may determine the traffic density there. To do this, we first scan all the related items in the target area, removing smaller or overlapping objects, and then label the cars in that area.

To address the issue of noise introduced by varying lighting conditions during the day, a series of reference photos were taken and saved at various intervals. The system iteratively uses the current time of day to cycle among these reference photos.

Our project outcomes are as follows, based on the currently implemented hardware:

Density Count	Delay in Light
20 vehicles	5 sec
30 vehicles	10 sec
40 vehicles	15 sec
50 vehicles	20 sec

CONCLUSION

A revolutionary solution to the long-standing problems of urban traffic management may be found in the Internet of Things (IoT)-enabled detection of traffic violations and dynamic regulation of signals using image processing. In contrast to traditional systems that depend on predetermined cycles and human oversight, this integrated architecture for continuous monitoring, precise detection of violations, and adaptive signal functioning. Internet of Things (IoT) sensors and image processing algorithms guarantee accurate detection of traffic law breaches like lane indiscipline, overspeeding, and red-light jumping. While doing so, dynamic signal adjustment minimizes traffic jams and fuel waste by adjusting the flow of traffic according to density and trends. The system's advantages go beyond just regulating traffic. It helps reduce emissions while vehicles are not in use, which improves road safety, aids law enforcement, and helps the environment. Also, by revealing locations prone to accidents and heavy traffic, the collected data may help with long-term urban planning. There is tremendous promise for efficiency, security, and sustainability, despite

obstacles associated with infrastructure investment, data security, and network stability. Intelligent traffic systems provided by the Internet of Things are not only practicable, but essential, in the context of smart city development. With this new innovation, we can make roads safer, transit more efficient, and cities smarter so they can handle the complicated needs of contemporary transportation.

REFERENCES

- [1] Aakash, S., & Vimal, M. N. (2020). IoT-enabled real time traffic management system. *International Journal of Advanced Science and Technology*, 29(5), 11439–11449.
- [2] Aditi, A., & Mousami, V. (2017). IoT-based dynamic road traffic management for smart cities. *Journal of Advanced Research in Dynamical & Control Systems*, 13(Special Issue), 777–782.
- [3] Ashwin, S. C., Karthik, S. K., & Allwyn, R. P. (2020). Real time motion detection for traffic analysis using computer vision. *International Journal of Computer Vision and Image Processing*, 10(2), 1–14.
- [4] Bhavana, P., Likhitha, P., Manoj, C., & Kumar, L. S. (2023). IoT-based dynamic road traffic management system. *Journal of Physics: Conference Series*, 2466(1), 12–25.
- [5] Chaus, N., Pailwan, A., Chavan, S., Nagavkar, R., Kumbhar, S., & Pande, S. (2022). Traffic analysis using image processing to alert traffic control. *International Journal of Advanced Research in Science, Communication and Technology*, 5(3), 1164–1169.
- [6] Harshini, V. H., & Nataraj, K. R. (2017). IoT-based intelligent traffic control system. *International Journal for Research in Applied Science & Engineering Technology*, 5(5), 707–711.
- [7] Janahan, S. K., & Veeramanickam, M. R. M. (2018). IoT-based smart traffic signal monitoring system using vehicles counts. *International Journal of Engineering & Technology*, 7(3), 309–312.
- [8] Janahan, S. K., Veeramanickam, M. R. M., Arun, S., Narayanan, K., Anandan, R., & Parvez, S. J. (2018). IoT-based smart traffic signal monitoring system using vehicles counts. *International Journal of Engineering & Technology*, 7(12), 310–311.
- [9] Krishnan, S. (2016). Traffic flow optimization and vehicle safety in smart cities. *International Journal of Innovative Research in Science, Engineering and Technology*, 5(5), 7814–7820.
- [10] Kshirsagar, S. P., & Mantala, P. H. (2017). Intelligent traffic management based on IoT. *International Journal of Computer Applications*, 157(2), 26–28.
- [11] Li, Z., Shahidehpour, M., Bahramirad, S., & Khodaei, A. (2017). Optimizing traffic signal settings in smart cities. *IEEE Transactions on Smart Grid*, 8(5), 2382–2393.
- [12] Manikanta, C., Raghavendra, G., & Arun Ku, M. (2018). A novel IoT-based intelligent traffic information system using integration and agent technology. *International Journal of Advanced Research in Computer Science and Software Engineering*, 8(6), 105–112.
- [13] Parate, M. (2024). IoT-based smart traffic management system using image processing and automated street lighting system. *International Journal for Research in Applied Science and Engineering Technology*, 12(9), 570–573.
- [14] Sakhare, N., Tatale, S., Sakhare, S., Dusaane, H., Puri, M., Girme, P., Sankpal, R., & Ghule, P. (2020). Image processing and IoT-based dynamic traffic management system. *International Journal of Scientific Research in Science, Engineering and Technology*, 7(2), 180–188.
- [15] Sharma, S., Giradkar, V., Sanap, A., & Sarolkar, S. (2018). IoT-based traffic light controller in smart city. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, 7(1), 117–123.
- [16] Sowmya, M., Anusha, P. S., Ashwin, S. M., Jones, J. S., & Pinto, L. W. (2016). IoT-based traffic management system. *International Journal of Innovative Research in Computer and Communication Engineering*, 5(11), 16408–16410.
- [17] Subramani, N., Berlin, M., Tripathi, S., Devi, V., Bhardwaj, I., & Natarajan, A. K. (2021). IoT-based traffic prediction and traffic signal control system for smart city. *Soft Computing*, 25(3), 1–9.
- [18] Vimal, M. N., Aakash, S., & Batcha, S. (2020). IoT-enabled real time traffic management system. *International Journal of Advanced Science and Technology*, 29(5), 11439–11449.