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AI-BASED YOLO V4 INTELLIGENT TRAFFIC LIGHT CONTROL SYSTEM

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Abstract:
With the growing number of city vehicles, traffic management is becoming a persistent challenge. Traffic bottlenecks cause significant disturbances in our everyday lives and raise stress levels, negatively impacting the environment by increasing carbon emissions. Due to the population increase, megacities are experiencing severe challenges and significant delays in their day-to-day activities related to transportation. An intelligent traffic management system is required to assess traffic density regularly and take appropriate action. Even though separate lanes are available for various vehicle types, wait times for commuters at traffic signal points are not reduced. The proposed methodology employs artificial intelligence to collect live images from signals to address this issue in the current system. This approach calculates traffic density, utilizing the image processing technique YOLOv4 for effective traffic congestion management. The YOLOv4 algorithm produces better accuracy in the detection of multiple vehicles. Intelligent monitoring technology uses a signal-switching algorithm at signal intersections to coordinate time distribution and alleviate traffic congestion, resulting in shorter vehicle waiting times.

Keywords: *Traffic jams, traffic light system, traffic management, intelligent monitoring, signal switching algorithm, artificial intelligence*

1. Introduction

As the quantity and volume of vehicles populating the roads, especially in metropolitan cities, are increasing , intra-city roads are facing issues related to capacity, congestion, and control. The current traffic management system requires a great deal of effort and manpower to avoid and prevent accidents and imposes long waiting queues at the crossings. A more sophisticated system and infrastructure is required for better traffic management. Intelligent transportation systems are the need of the hour for a better traffic management. WSN (wireless sensor networks) can be used in single and multiple intersections for controlling vehicle movement flow sequences [27]. Traditional traffic control systems involved manual operation of control systems, which required a good amount of manpower, managing congestion by traffic police using signboards, a sign light, and a whistle.

Sensors and timers play a crucial role in managing vehicle movement at a traffic signal.

Electronic Sensors: Installing loop detectors or proximity sensors on the lane is another sophisticated option. This sensor collects information on the flow of traffic on the route. Sensor data is utilized to control traffic lights.

Traditional timer-controlled traffic lights: Timers are utilized to keep track of these signals. The timer is set to a specific numerical value and the lights alternate between red and green based on the timer value.

Following a comprehensive literature review, we discovered various techniques for detecting vehicle density and acting on it. As a result, we decided to create an adaptive traffic control system that recognizes objects in images and adjusts the timing of traffic signals as required. Traditional techniques have many disadvantages. Setting up the manual control system requires substantial time and work. Due to a labor shortage, we cannot have traffic officers manually managing traffic in all regions of a city or town. As a result, a more effective traffic control system is required. Static traffic management uses a signal with a timer for each predetermined period and does not respond to on-road traffic. Because high-quality data gathering often relies on complex and expensive equipment, and the number of facilities may be restricted owing to budget constraints, accuracy and coverage are frequently at odds when utilizing electronic sensors such as proximity or loop detectors [28].

Furthermore, because most sensors have a limited effective range, a network of facilities normally requires many sensors to offer comprehensive coverage. Live images from CCTV (closed-circuit television) cameras at traffic junctions are used to calculate real-time traffic density by recognizing the number of cars at the signal and appropriately modifying the green signal time. To precisely estimate the green signal period, the vehicles are classified as a car, bike, bus, truck, human, and bicycle.

The YOLO (from "you only look once") approach is used to identify the number of cars where the traffic signal timer is adjusted in the proper direction based on vehicle density related to detected images. As a result, green signal intervals are optimized, and traffic is cleared much more efficiently than in a static system, resulting in fewer unnecessary delays, congestion, and waiting times. The hardcoded traffic signal allocation systems will not have the knowledge of traffic density. They involve long waiting times, especially in densely populated cities, resulting in heavy traffic jams and congestion. In addition, sensor-based traffic management reduces the problem to some extent but requires regular maintenance. Hence, there is still scope for improving the signal time allocation, which reduces traffic jams and congestion to a large extent. As a result, we propose to create an automated traffic management framework based on artificial intelligence that has a broad understanding of traffic density. This fits in to the proposed model of research work. This introduction is followed by literature review in the associated areas of research under section II. Methodology of the proposed problem is discussed in section III and results of the work with an analysis is mentioned in section IV followed by a conclusion.

2. Literature Review

RFID (radio-frequency identification) tags use radio waves to transmit data about an object to an antenna/reader combination. P. Manikonda, A.K. Yerrapragada, et al. [11] developed a method for detecting vehicle speed that included an RFID tag and an RFID reader. The average speed of specified (N) readers' cars was utilized to calculate the average time at particular crossings. This, however, necessitates constant communication between tags and readers and the installation of RFID tags in every vehicle. A. Kanungo, A. Sharma, et al. [7] used no hardware and computed vehicle density using a background separation technique at 30 frames per second, adding picture matrices. The next step was to divide the result by a constant C (c=camera height*number of rows*number of columns*30). The time to signal at four-way junctions is determined by vehicle density. It's green time! (minimum: 10 seconds, maximum: 60 seconds) The concept was good; however, the study failed to consider the vehicle's starting and count, both of which are essential aspects. The computation procedure had to be rapid because the vehicle movement remained constant.

Qingyan Wang et al. [20] proved that their YOLOv4 algorithm had been improved to develop prediction capacity. In the detection trial, the author's algorithm area under the PR curve (AUC) was 97.58 percent, compared to 90 percent in the Vision for Intelligent Vehicles and Applications Challenge Competition. In the recognition experiment, the mean average precision of the Improved YOLOv4 method was 2.86 percent higher than that of the original YOLOv4 technique. The Improved YOLOv4 algorithm is a reliable and effective real-time traffic light signal detection and recognition solution. Dave, Pritul, et al. [21] proposed a two-step process for YOLOv4 and XGBoost Traffic light system. The first step is to count the cars in each class. The method is done using YOLOv4 object detecting technology. It employs an ensemble algorithm called XGBoost to predict the optimum green light window time (eXtreme gradient boosting). The suggested method is also compared with other YOLO implementations and prediction systems. The XGBoost algorithm produced the most efficient YOLOv4 results in accuracy and inference time. The proposed method might reduce traffic delays by 32.3 percent on average. A. Zaid, Y. Suhweil, et al. [1] developed an electronic and dynamic system that includes the measurement of Green Light Phase Time (GLPT) and an electronic system equipped with a faster C-language-based algorithm to provide a visualization of roads for remote control from the head office. For the vehicle detection algorithm, there are 12 LEDs for traffic light status and four limit switches (GLPT: EGT = FR x C, PGT = EGT + S - Y, RGT = EGT - PGT). However, the headquarters must dictate the orders, which necessitates human involvement to avoid this. K. Sangeetha, Ms. Kavibharathi, et al. [12] proposed a Prewitt Edge Detection Mechanism to enhance the captured multiple images to reduce the light. These images were compared with images stored in the database to calculate the mean of matching percentage (0-10)% -90sec, (10-50)%- 60 sec,(50-70)%-30sec,(70-90)%-20sec). Here the Constant gamma values are used, which leads to more intensity reduction. The Internet of Things (IoT) and sensor-based technologies have already shown considerable progress in various fields. So J.M.S. Ferdous, T. Osman, et al. [13] tried it out by capturing images with a VCO7O6 camera and sending them to a microcontroller embedded in an Arduino. They can be sent to a server, where a background subtraction algorithm is used to detect vehicles. The server adjusts the green signal time and red signal time in a four-way junction server, and the traffic junction connection is maintained using the HTTP protocol. When vehicle density is poor, photos of the background are taken every 6 hours, which is entirely carried out in Indonesia and requires an essential factor of continuous background light monitoring.

Jinyang Li, Yuanrui Zhang, et al. [9] proposed SATL (self-adaptive control traffic light systems) to improve the self-adaptive traffic signal timer by considering vehicle speed. Vehicles have a data-gathering module and a sending module that sends data to traffic light recipients. For an algorithm to assign time and increase time in case of collision or injuries, signals using a ZigBee sender with a range of 100 meters and Vmax = 40km/hr and Vmin = 20km/hr are considered, and increasing time in case of collision or accidents. However, vehicles slow down when making a turn, which is also essential at intersections, so S. Vignesh, K. S. Naresh, et al. [15] built a system of infrared sensors mounted on either side of the road that detects vehicle motion and sends the information to a Raspberry Pi connected to signals. This Raspberry Pi changes the signs with a more extended green time allocation when the number of vehicles detected by the IR sensor is high. Before projecting into the road, a traffic analysis allows us to take alternate lanes and avoid delays.

P. Rizwan, K. Suresh, et al. [16] came with vehicle detection sensors, and sensor data is used to compute time for traffic light timing adjustments. Input from camcorders and sensors is used to build a mobile application that includes images and timings to find shortcut routes to the destination considering the four-way junctions. Khushi [8] proposed a method in which pictures collected at intersections are sent to Matlab code for morphological image generation, and traffic density is measured using Matlab Duration functions. The length of green and red lights associated with a specific junction is calculated and sent to Arduino (Tdur=Tmax-k*Tmax) (East-West-North-South). According to Muhammad Fachrie's research [10], many issues have been resolved due to recent advances in ANN, which has been a key cause for the establishment of numerous firms. An Artificial Neural Network with a sliding mechanism with predefined bounding boxes was developed to finalize the number of vehicles on the normalized picture. Additionally, a fuzzy-based traffic signal controller was proposed, dividing traffic range into low, little low, medium, little high, and high and adjusting signal timings. To improve detection accuracy, A. Chattaraj, S. Bansal, et al. [3] modified the existing YOLO algorithm to OYOLO and OYOLO+R-FCN by combining both algorithms, varying the learning rate of epochs, and running the algorithms based on the requirement of accuracy.

According to P. Adarsh, P. Rathi et al. [2], model-based tracking employs an intra-frame matching method based on a parameterized vehicle model. An image segmentation component first recognizes possible moving vehicles by recognizing moving characteristics in the picture. H.F. Chong and D.W.K. Ng [4] utilized a technique known as region-based tracking to detect and monitor related areas in a picture associated with each vehicle. A background subtraction approach is widely used in the strategy. When automobiles partly obstruct each other in congested traffic, this technique fails because the algorithm recognizes the vehicles as a single huge blob in the foreground picture, lowering the process's accuracy. A Haar-like feature detector with a high level of accuracy was used to find cars. S. Choudhury, S.P. Chattopadhyay, et al. [5] presented Haar-like characteristics by evaluating neighboring rectangular sections, adding the pixel intensities in each area, and subtracting the amounts. It will be used to categorize different parts of the image. Pranav Shinde and Srinand Yadav made the YOLO algorithm and [14] proposed a system that would use a Raspberry Pi USB camera to record video of vehicles when the light was red. The video would then be sent to a cloud system, where a YOLO algorithm would measure the number of vehicles and their lane preferences to turn on the green light. A difference in light intensity almost always causes foreground separation. This is a unique idea for extracting moving objects using a context subtraction process.

Asma Ait Ouallane et al. [22] initially covered routing systems, traffic light solutions, and ways for controlling network traffic. Following that, the author explores potential options. Finally, they suggest many fresh possibilities for future urban highway traffic management research. AI-based techniques can reduce the challenges associated with effective road traffic management, particularly at junctions, which are a key cause of road congestion. B. Ali Almansoori et al. [23] developed an AI-powered system for identifying left-approaching automobiles at a roundabout. The system controller captures video data from roundabouts and uses a trained neural network to identify vehicles. When a vehicle is detected from a specific distance, signaling lights flash red to indicate a stop and green to indicate a pass. The proposed method reduces automobile accidents, roundabout delays, fuel economy, and loss of public property. D.Y. Huang., Chao Ho Chen., et al. [6] developed a unique concept for extracting moving things using a context subtraction process. Swinging tree leaves and raindrops are removed using two back-to-back filters in this example. Furthermore, a shade removal process combines a flexible background deletion approach to exclude mobile vehicles from background photos. Zhang X., Li X. et al. [17] propose a hybrid algorithm in which tiny-YOLOv3 and quick RCN are trained with images of various dimensions (320,416,608) and compared, with results presented as graphs and mean accuracy precision calculated. J. Hussain et al. [25] came up with the idea for YOLOv4, which has better inference methods. YOLOv4 is 12 percent faster than its predecessor, YOLOV3, and it is twice as fast as the EfficientDet method on the Tesla V100 GPU. The algorithm didn't work well on traditional computers and single-board devices. In this study, we look at how well inference works in several different frameworks. We then suggest a framework that needs less than 30% of the hardware other frameworks need. In order to reduce traffic congestion, Muhammad Saleem et al. [26] suggested a fusion-based intelligent traffic congestion management system for VNs (FITCCS-VN) that gathers traffic data and guides traffic on available routes in smart cities. In order to avoid traffic congestion, the proposed system would provide drivers with unique features such as a distant view of traffic flow and the number of cars on the route. The recommended technique both boosts traffic flow and reduces congestion. The suggested method has a success rate of 95% and a failure rate of 5%, which is higher than existing methods.

People spend more time commuting to work, school, shopping, social events, and navigating traffic lights. Signal allocation is now typically dependent on a timer in many cities worldwide. The timer solution has the disadvantage that even though there is less traffic on a route, a green signal is still assigned until its timer value decreases to 0. In contrast, traffic on another road, which is extremely busy, receives a red signal at that point, causing congestion and time loss for citizens. Most current applications are not automated and are susceptible to human error.

Current research introduces an innovative and intelligent control system to solve such issues. An intelligent traffic light system should be implemented to sense vehicles' presence and absence and react accordingly. The following objectives have been developed based on current research and literature. 1. Create a computer vision-based traffic signal controller that can adapt to the current traffic scenario. 2. Assess traffic density by recognizing cars at traffic lights using real-time photos from CCTV cameras at traffic intersections. 3. Calculate the green signal time for vehicles such as cars, buses, motorcycles, trucks, and people.

3. Methodology

This section talks about the methodology followed for conducting this research work, employing the YOLO approach for effective traffic management system in vehicle movements.

YOLO is a state-of-the-art object detection algorithm that is incredibly fast and accurate. YOLO is a clever convolutional neural network (CNN) for multiple objects recognition. The algorithm divides the image into regions and predicts bounding boxes and probabilities for each area using a single neural network applied to the entire image. The weighting of these bounding boxes is based on the anticipated changes. It can create a large amount of data that contains all of the information included inside the image. A single CNN forecasts various bounding boxes and class probabilities for distinct packages based on the YOLO algorithm. YOLO increases its detection performance by the training process on the captured set of photographs. The backbone CNN, which is utilized in YOLO, may be tuned further to improve processing performance. Darknet is a C and CUDA- based open-source neural network architecture. It is fast to set up and supports both CPU and GPU computing. On ImageNet, YOLO achieves a top-1 accuracy of 72.9 percent and a top-5 accuracy of 91.2 percent using DarkNet. Darknet primarily employs 3x3 filters for feature extraction and 1x1 filters for output channel reduction. It also uses global average pooling to make predictions [18].

3.1 Object Detection

The model was created utilizing Python programming language and entirely developed in Google Colab, which included various packages and frameworks to execute the previously mentioned algorithm. The model was developed using OpenCV functionalities to construct the YOLOV4 algorithm with 53 convolution layers. Blob from Image was used to change the image's scale and dimension before passing it into the algorithm. cv2.dnn.readNetFromDarknet was used to read the weights and load the configuration file to load the CNN layers of the algorithm. The multiple boxes generated in each grid for each object are removed by taking the threshold value into account. Finally, Non-max suppression is used to find the best box for the object. These values are utilized to point the objects (car, truck, motorbike, person, bus), and cv2.rectangle for rectangular boxes (x,y,w,h) around the objects; different color classes are used for generating object names concerning the vehicle. The average time of the vehicle required to cross the lane is calculated based on the type of vehicle.

3.2 Simulation Environment

Pygame is a series of cross-platform Python modules for making video games and simulations. It consists of computer graphics and sound libraries programmed to work with the Python programming language, which incorporates AI, mathematics, and Pygame, extending the excellent SDL library. This enables users to write full-featured games and multimedia applications in Python. Pygame is very compact, running on almost every platform and operating system. We use Pygame's functionalities to create vehicles at random and monitor their motion by updating their coordinates regularly. We use threading, a technique for performing several tasks at once. We keep the traffic signals up to date. Time functions are used to keep track of the time in seconds and do the job. Load is used to make images of cars, and blit keeps our eyes open.

3.3 Approach Adopted in YOLO

The advantage of using YOLOv4 over other versions and algorithms is that it addresses the drawbacks of image processing taking a long time and GPU utilization. When compared to different versions of YOLO, the detection accuracy is high. Furthermore, compared to YOLOv3, AP (average precision) and FPS (frames per second) increased by 10% and 12%, respectively.

The intelligent traffic detection model built in this study is a traffic management extension of the YOLO algorithm. The objects detected by this algorithm aid in allocating the current signal timer. Detecting multiple images using R-CNN algorithms takes a long time. It has a high computational complexity, so YOLO was created in 2011 after a lot of research work in image processing to detect multiple images of images effectively in a short period. The algorithm's accuracy has been demonstrated by using a simulation in which different vehicle density levels at crossings are randomly dispersed in all directions at random intervals. Compared to the default vehicle passage using the hardcoded approach, the signal switching algorithm increases the number of cars that may pass through in a given amount of time, aiding in vehicles' efficient and continuous movement. Every time the algorithm captures images and identifies vehicles in images, it takes 15 seconds, so we make efficient use of this time to minimize traffic congestion.

Figure 1 shows the lineage of steps specified in the proposed model. It starts from CCTV footage with refined images and ends at directioned traffic signal aided by timer.

4. Results and Discussion

This section elicits a brief description of results obtained and studied for the purpose of providing an

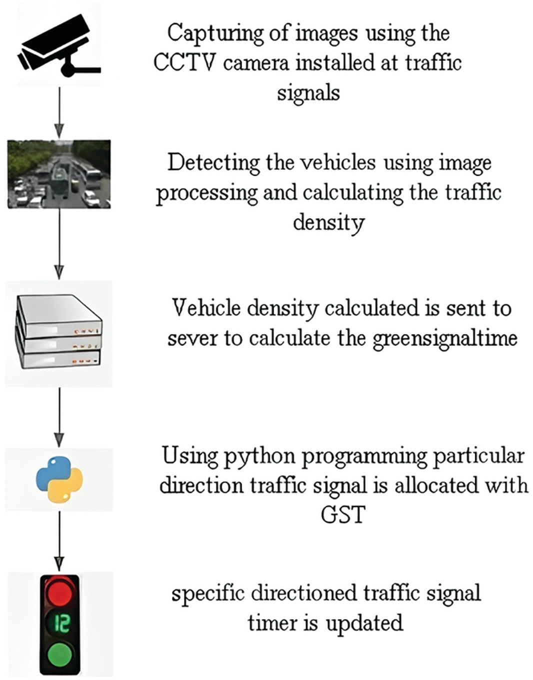

Fig. 1. Proposed System Model

effective traffic light management system powered by the YOLO algorithm. Appropriate photographs, respective graphs and tables are shown in this section for a better visibility of the proposed work carried out.

Equation (4.1) shows the Green Signal Time (GST) based on vehicle density.

$$GST = \left[\frac{\sum Noofvehicles_{vehiclesclass} * averagetime_{vehicleclass}}{Nooflanes} \right] \tag{4.1}$$

Where GST (Green Signal Time) is green signal time, the number of vehicles of each type of vehicle detected by the vehicle detection module is 'NoOfVehiclesOfClass'. 'AverageTimeOfClass' is the time it takes for vehicles of that class to reach an intersection on average. The 'NoOfLanes' variable shows how many lanes there are at the intersection. The average time for each type of vehicle to pass through a junction can be adjusted depending on the surrounding environment. Depending on the intersection's features, this can be done region-wise, by city, or even by neighborhood. It is possible to evaluate data from the respective transportation authorities. The signals are exchanged cyclically rather than being switched in order of densest to least dense. This is consistent with the new system, which allows people to change their routes because the signals turn green in a fixed pattern. The order of the signs has remained unchanged, except for the yellow signals, which have been considered.

The average time for each type of vehicle to pass a junction can be altered based on the area, region, city, locality, or even intersection-wise based on the intersection's qualities to enhance traffic management. Figure 2, Figure 3, and Figure 4 show different object detection algorithm analysis for traffic at a crossroad in the daytime using YOLOv4 algorithm. Figure 2 demonstrates the identification of objects with respect to type of vehicle. Figure 3 depicts the traffic density at traffic signals. Figure 4 is the display of the objects moving identification at traffic signals.

4.1 Analysis and Discussion

This section elicits an analysis of results obtained and studied for the purpose of providing an effective traffic light management system powered by the YOLO algorithm.

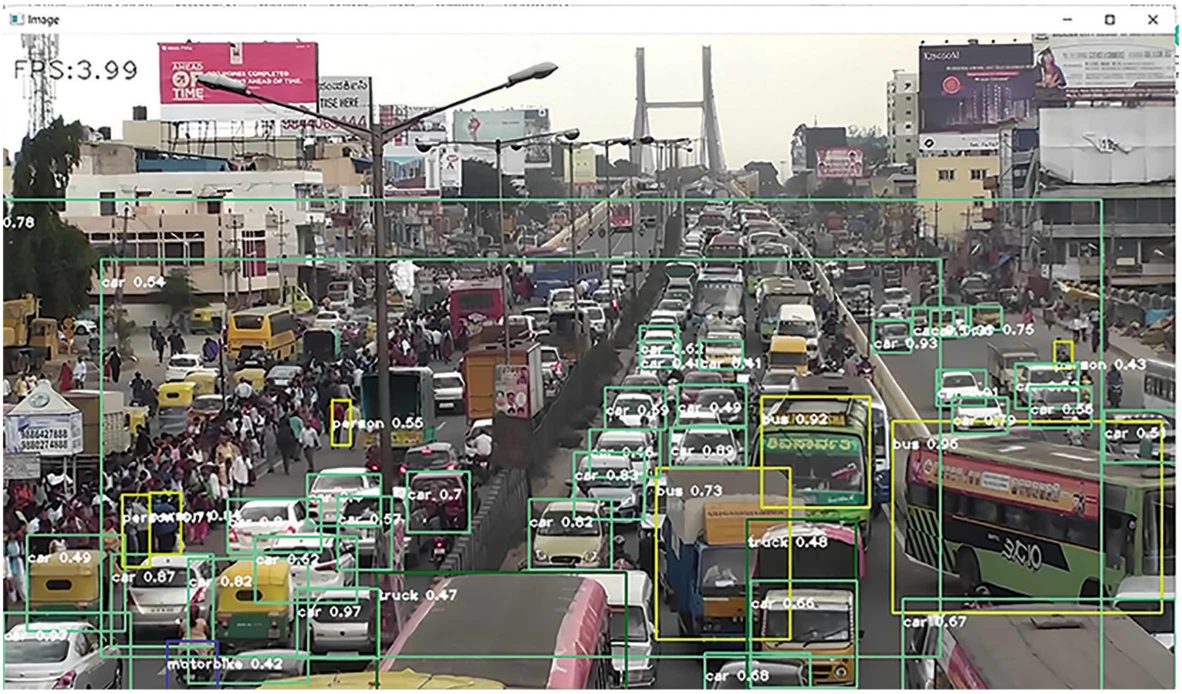

Fig. 2. Image captured from city traffic

Fig. 3. Image captured from the near bus station

Fig. 4. Image captured from signal traffic

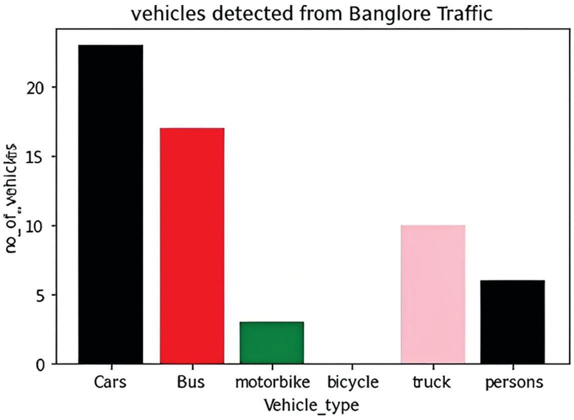

Fig. 5. Graphical representation of Bangalore traffic

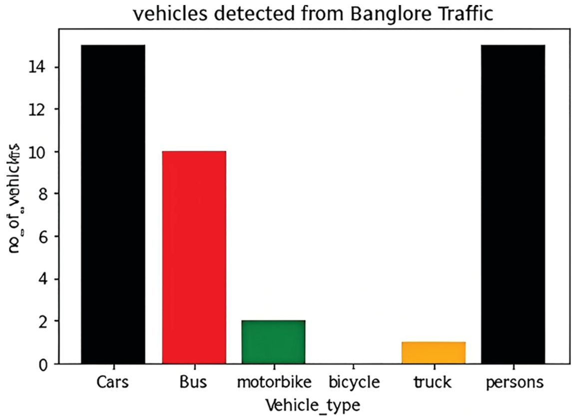

Fig. 6. Graphical representation of Bangalore traffic near Bus station

Figure 5 depicts an investigation of vehicles identified at Bangalore (a metropolitan city in the country of India) traffic signals. It infers a good number of cars identified using this algorithm. Figure 6 depicts the study of cars and pedestrians observed at Bangalore bus terminals, which indicates the identification of both objects. Figure 7 represents a vehicle detection analysis in Mumbai (a metropolitan city in the country of India) traffic. As a result of huge traffic in the Mumbai region, the movement of cars present at the crossroads has grown exponentially. According to the experiment carried out in the research, Figure 5 and Figure 6 showcase Bangalore traffic which is a mix of vehicles and people, but Mumbai traffic is more focused on vehicle type rather than pedestrians. As a result, the research calls for the use of intelligent traffic systems that need less traffic signal time. Table 1 illustrates the time allocated for the green signal in both experiments in Bangalore and Mumbai respectively. Figure 8 demonstrates a considerable improvement in the number of vehicles passing in less time, demonstrating the validity of the suggested technique as an intelligent traffic system.

Table 2, Table 3 and Table 4 show the number of vehicles crossed at respective lanes of existing timer, proposed system, and total green signal time allocation (seconds) for different phases of time at respective lanes. Based on the inference of Table 3, if the numbers of vehicles are increasing. the intelligent timer optimized according to the number of vehicles passes to the signals. Table 4 shows the difference of time elapsed on 400 will be different than the time elapsed on 160 due to the optimization of time interval. This research aims to reduce traffic congestion and pollution, and increase vehicle passage per day, especially at busy intersections. The YOLOv4 algorithm produces better accuracy in the detection of multiple vehicles depicted in the image, with a detection accuracy of 80-85 percent based on vehicle density in the image. We also obtained a substantial improvement in the passage of vehicles per unit of time with simulation as compared to the default hard-coded scheme. It increased the total flow of vehicles in all lanes. The built model is limited to four-way intersections and can also be used

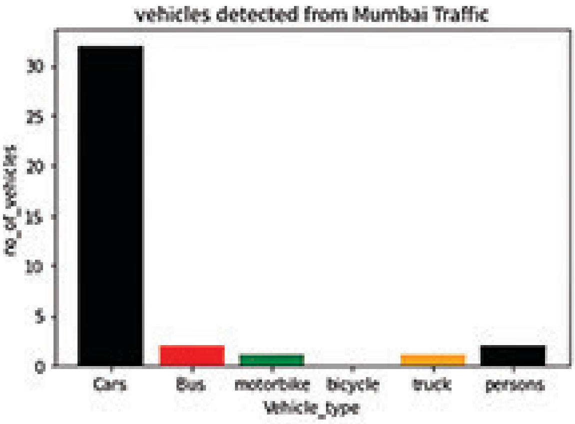

Fig. 7. Graphical representation of Mumbai traffic

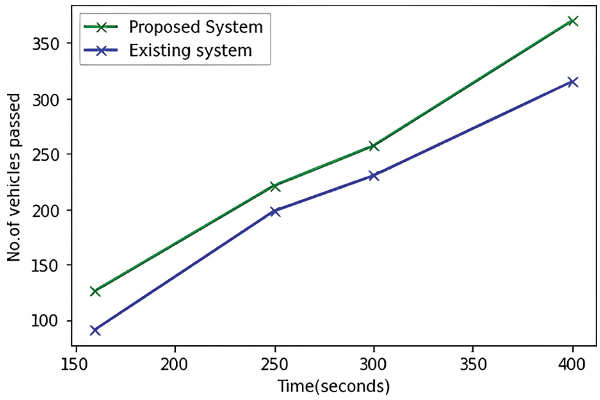

Fig. 8. Existing system vs. intelligent traffic control system

Tab. 1: Green signal Time Allocation

Figure Number	Location	Allocated Time in seconds
1	Bangalore	43 seconds
2	Bangalore	24 seconds
3	Mumbai	25 seconds

Tab 2: Number of vehicles crossed at respective lanes of existing timer

Time elapsed	Lane1	Lane2	Lane3	Lane4	Unit time
160	19	34	16	22	0.568
250	96	69	13	20	0.792
300	88	87	28	30	0.766
400	121	108	41	40	0.787

Tab 3: Number of vehicles crossed at respective lanes of intelligent timer

Time elapsed	Lane1	Lane2	Lane3	Lane4	Unit time
160	40	55	15	16	0.787
250	77	86	34	24	0.884
300	106	91	23	37	0.854
400	135	138	27	40	0.925

Tab 4: Total green signal time allocation (seconds) for different phases of time at respective lanes

Time elapsed	Lane1	Lane2	Lane3	Lane4
160	46	33	22	20
250	72	75	36	20
300	117	71	33	33
400	124	112	36	43

in high-vehicle-density areas. The project is primarily concerned with traffic, especially in metropolitan cities with large populations.

Conclusion

The proposed YOLOv4 algorithm recognizes numerous vehicles in a picture with an accuracy of 85 percent depending on vehicle density, and we obtained a considerable increase in numbers of vehicles passing per unit of time using simulation, compared to the default hard-coded technique. There was greater traffic on all lanes. The developed model may be used in high-vehicle-density areas and four-way intersections. The research focuses on urban transportation. The proposed method also alters the green signal time automatically based on traffic intensity at the light, guaranteeing that the direction with more traffic obtains a longer period than the one with less traffic. This would prevent annoying delays while also reducing traffic and waiting times, resulting in decreased fuel usage and emissions. The simulation findings show that the system would be a major improvement over the existing method in terms of the number of cars crossing the junction. This gadget may be improved to function even better with additional calibration and the use of real-world CCTV data to train the model.

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