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An Improved Smart Traffic Signal using Computer Vision and Artificial Intelligence

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***Abstract**: The growth in population all over the world and in particular in India causes an increase in the number of vehicles which, create complications regarding traffic jam and traffic safety. The primary solution to recover the jam condition is the expansion of capacities of roads by building new streets. However, this requires extra efforts and more time that is a costly and ineffective solution. Therefore, there is a need for alternative solution methodologies that are being implemented. Intelligent traffic monitoring is a branch of intelligent transportation systems that focuses on improving traffic signal conditions. The key goal of such an intelligent monitoring system is to improve the traffic system in a way that reduces delays. Many cities facing these delays because of the inefficient configuration of traffic light systems which are mostly fixed-cycle protocol based. Therefore, there is a profound need to improve and automate these traffic light systems. The establishment of a mixed technique of artificial intelligence (AI) and computer vision (CV) can be desirable to develop an authenticated and scalable traffic system which can aid to solve such problems. Proposed work supports the use of computer vision technology to build a resource-efficient, synchronous and automated traffic analysis. Video samples were collected from multiple areas to use in the system. The system applied and the vehicle was counted and classified into different classes. Manually and automatically annotated patterns were used for the classification. The multi-reference-line mechanism employed to find the speed of the vehicle and analyze traffic. The system makes its decision based on a number of vehicles, backwards-forward synchronous data and emergency conditions.*

Keywords: Computer Vision, Synchronous Traffic Signals, Object Detection, Artificial Intelligence, Machine Learning, Multiline Reference.

I. INTRODUCTION

The goal of transportation research is to optimize the transportation flow of people and goods. As the growing population, the number of travellers constantly increases while resources provided by current Infrastructures are not sufficient for this, therefore intelligent control of traffic became a really serious issue. Traffic in the urban areas is generally based on fixed cycle traffic signal lights, which is not properly configured in many cases and causes unnecessary extra waiting times for the vehicles [1]. The traditional traffic signal monitoring techniques include fix-interval monitoring, day time monitoring, vehicle actuated and semi-actuated monitoring, green wave monitoring, area dynamic monitoring and area static monitoring. However, there is no system which we can call a capable and effective system or can be adopted in real-world effectively. This is because the traffic control system is non-linear, non-deterministic and fuzzy, and thus established methods of modelling and control cannot work very well. In order to answer the above-mentioned problem, there are numerous researchers' groups have performed a lot of studies. In recent years the application of image processing methods in automated traffic monitoring and control system has been reviewed to optimize methodologies for traffic controls. We also have the ever-increasing problem of the traffic violation. Minimizing the number of violations brings more order and reduces the number of accidents. Currently, the monitoring approaches of traffic violation are not effective and good enough in the many of the cases. Radar guns are another thing used in some cases. However, radar guns can not aim at multiple vehicles and a lower distance. Therefore, we have applied computer vision and machine learning technologies to inhibit these violations by the traffic monitoring system. To decrease the dependence on traffic police and improve efficiency, we have used cameras that provide greater scope for automation. Detecting vehicle in huge traffic data is one of the serious issues in computer vision. The proposed paper is an attempt to detect the actual vehicle and count and detect the speed of the same. These observations are not limited to a single traffic signal. We introduce a new concept of synchronous data sharing with the same directional backwards-forward traffic signals that provide better results for automation. We not only determine the violations but also detect the actual vehicle that provides extra information regarding the emergency (in case of a vehicle is an ambulance) in the traffic and jam situation in the respective area. It can be used to determine the peak hours and plan the traffic management layout according to the overall analysis of the system data. The proposed system takes input as the top view footage of the installed camera on the traffic signals. Installing the camera on the accurate and at the right position is the tough process. However, it is a one-time expenditure system and more effective and long-lasting. In the proposed system, there is a minimal chance of camera deterioration. But the sensor-based systems did not have this case. Sensors that are used to detect the density of the lane can be deteriorated because they are installed onto the pavements directly. Hence, CV based system has a more flexible installation process and increase the portability, efficiency and durability of the system.

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This paper aims to propose an intelligent synchronized traffic signal monitoring system to improve traffic monitoring and enhance the way we are dealing with some other problems and the situations related to transportation. It will be in the intelligent traffic system. Thus, an intelligent traffic monitoring system will be formed of two segments (or subsystems): a control system and a monitoring system will able to integrated together to help the traffic system to take the smart decisions efficiently. This research will be examining the additional component (monitoring system) by using synchronous data sharing between its control system. This system will be capable to identify a different type of vehicles, their speed, and determine the crowded street case, normal street case and empty street case. The input of this system will be a sequence of images of vehicles of the crossing to be monitored. Technically, the proposed method has two stages: training stage and recognition stage which uses one video camera to every crossing of the area. These cameras fixed in a suitable position and use multi-connect architecture based multi-line reference techniques [3] to detect the level of the crowd in the lane.

II. MOTIVATION AND NEED OF STUDY

The growing momentum for building more sustainable transportation systems has provided an important focus of this research work. The second focus of this research was driven by the potential of computer vision and machine learning techniques for solving well-entrenched problems in the traffic element analysis. Traffic jam has a number of negative impacts such as wasting of valuable time. Delay in the traffic that may affect in late presence for school, office, and employment etc. makes us unable to guess accurate travelling time. It also a reason of wasting fuel and pollution. Traffic jam may also block the path of emergency vehicles travelling. Congestion in traffic also increases the chance of vehicle collision due to a narrow distance between them. Researchers have done many works to overcome all these problems but there is no effective universal solution to monitor traffic signal intelligently. Therefore, an intelligent system is required to detect vehicle type, count, speed and emergency condition. The underlying concept of proposed work focuses on synchronous traffic data sharing with backward-forward signals to monitor traffic effectively and manage emergency.

Several surveys and studies have estimated that on a day to day basis most of the jams or congestion in traffic happen due to a traditional traffic light control system. Most of the congestion in traffic is occur during the morning and evening time. It is nothing but an extra waste of time from people's daily life routine. During that time, the employers and students go to the office, University, college or school so they also are facing problems of delay in their office or institutions at the traffic light spot. Resources provided by present infrastructures are not sufficient as the traffic increasing with increasing population day to day. Therefore, the intelligent monitoring of traffic will become a very crucial issue in the upcoming years. Avoiding unwanted congestion would be profitable for both the economy and the environment.

The proposed intelligent traffic monitoring system is designed in such a way that can solve the problem of traffic congestion in metropolitan cities of the country and which will be a great option to save time and minimize the economic cost. By removing the traffic jams of cities, we can also decrease the additional use of energy resources like CNG, LPG or petroleum. India as a developing country most of the foreign currency spent on importing petroleum, and cannot afford to waste such an important resource.

III. RELATED WORK

Koller [6] proposed the model-based tracking system which uses a model of vehicle parameters for an intra-frame comparison technique. The system identifies the probable moving vehicle by extracting and identifying the parameters in the image. Coifman Benjamin, et al. [7] introduced a new technique of region-based tracking that identifies the regions of interest in the real image with each vehicle samples and tracks them. Mainly background subtraction technique was used in the system. However, this technique fails in overcrowded traffic situations because of vehicles overlap each other's view. In this condition, the system detects the vehicles as a single blob in the foreground image which reduces the accuracy. The Kalman filter-based technique helps the background view to develop the view with respect to the lighting, weather or time changes of the day. Active-contour tracking is another approach that uses active contour models for tracking. This approach reduced the complexity of computations. The next approach extracts sub-features and tracks them in the corresponding image that can be of distinct importance [8]. This approach gives an advantage of finding some differentiable features in the image by which system can detect vehicle more efficiently even when an overlap occurs. N.V. Chawla et.al. [9] and W. Liu et. al. [10] used a Haar-like feature detector for detection of vehicles which gives good accuracy. It works on pixel intensities, in the detection window it takes the adjacent rectangular area at a specific location and sums up pixel intensities in each area. Then differences of these sums are calculated which helps to classify subsections of the image. Zadeh [11] proposed a different technique that was based on fuzzy sets. Artificial neural networks technology also getting popular in the field of automation wherein new results are predicted on the basis of collected previous experience. However, many hybrid systems are also developed for urban traffic signal control [12]. Pena-Gonzalez et al. [13] discovered a plan which detects vehicles in real-time and it is made possible with the help of the vision-based system. A high-definition camera is installed on the signal to obtain real-time footage. At the same moment, different classification and clustering algorithms are used to process the same footage data. Their approach achieved an efficiency score of more than 95% in experimental test cases. Their system also gets a processing rate upto 30 fps in a 1280 x 720 resolution footage. Bhaskar et al. [14] also applied an image processing based method to track and identify the vehicles. Blob Detection methods and Gaussian mixture model are used to develop a unique algorithm which is able to track vehicle and recognize vehicle data at real-time. the proposed algorithm was a view to doing improvements.

Though this is a more efficient approach, in the condition of high traffic congestion it does not perform as expected. Ali et al. [15] and

Table- I: Recent Academic Studies in Vehicle Detection and Traffic Light System

Paper	Year	Method	Feature	Classification	Tracking
[17]	2018	Deep Convolutional Neural Networks	Colour point	Pixel calculation	Space tracking
[18]	2016	Computer vision techniques, including thresholding, hole filling and adaptive morphology operations	Grayscale comparison	Gaussian mixture	Reference line model
[19]	2015	Probabilistic prior maps and dense HoG	Colour	Majority pixel count	Hidden markov model
[20]	2014	Colour thresholding, BLOB analysis	HoG	Support vector machine	Correlation tracking
[21]	2012	BLOB analysis	2D Gabor wavelet	Nearest neighbour	-
[22]	2012	Colour difference enhancement, neighbourhood image filling, radial symmetry	Colour	Colour	Spatial-temporal consistency check
[23]	2011	Prior knowledge based state detection of vehicle	LBP feature	Support vector machine	-
[24]	2010	Colour thresholding, morphological operations	Haar feature	AdaBoost trained classifier	CAMSHIFT
[25]	2009	Gaussian-distributed classifier, BLOB analysis, temporal information	Colour	Global contradiction solving scheme	Temporal filtering / decision scheme

Kanungo et al. [16] offered an alternative method to control traffic signals. Cascade classifier along with OpenCV was used to recognize the traffic and take decisions over the real-time data.

Finally, a similitude is drawn between traditional traffic management and their proposed scheme.

IV. PROPOSED SYSTEM

Presented work proposed an intelligent traffic monitoring system, which uses computer vision and machine learning techniques with a customized data-sharing feature in two connected traffic signals. Proposed solution uses the following steps.

A. Vehicle Detection Procedure

Vehicle Detection is the primary step for the Proposed System. In this part, a well-placed camera in the street will send video as data to the main computer where, images will be analysed and vehicles will be detected. Instead of MATLAB, we are using OpenCV for the fast processing of the video footage of the traffic signals. The vehicle detection process is employed with the help of the cameras. The installed camera of the signal will send the footage output to the main system that will process that footage and gives further instructions to the control system after analysing the results. Two measurements are very important in the system to detect vehicles more efficiently. These two are:

1) Camera Placing Calculation

Vehicle detection is the elementary function of the system. It is very important to install a signal camera on an effective place to detect vehicle efficiently and accurately. By ensuring the major area coverage, we decide perfect angle and height for camera placing that yield high accuracy for the vehicle detection process. The proposed system will make a better decision if the camera coverage will be higher. According to the proposed system, we will install a camera on the traffic light post. The height range is very important and has to be calculated properly, by which our system can detect as many vehicles as possible in a street. From the different video samples with different heights, we have calculated that samples with a height range between 19 feet to 25 feet are processed effectively by our proposed system.
In Fig 1 shows the angle and height calculations for the camera placing. In the proposed work, we place camera at height of 25 (7.62 m) feet with base angle of 7 degree then

Rise = 7.62,

Base = $\frac{7.62}{\tan(7)}$

Top angle = (90°- 7°) = 83°,

Diagonal = $\frac{7.62}{\sin(7)}$

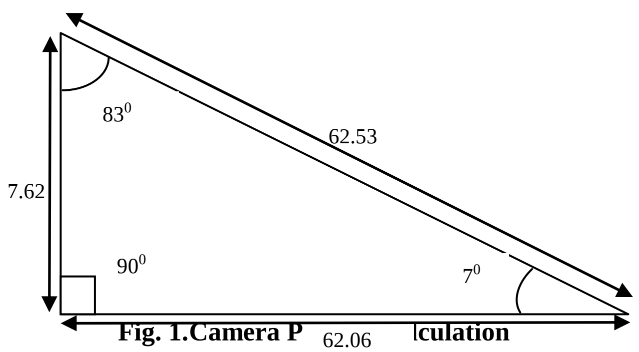

Fig. 1.Camera P lculation

Our primary goal is to get more than 30 to 40 vehicles in the frame. By this arrangement, we can perform detection of vehicles up to 62.06 meter.

Now we have to figure out how many vehicles would be possible to detect in the road within our detection range. For example an average length of a sedan car is approximately 4.5 meter; so,

$\frac{62.06}{4.5} = 13.791111 \approx 14$ Cars in one single column on the road.

There are three or four columns of car can accommodate on a four-lane road.
Therefore, assuming 3.5 columns of cars are there,
Then we will end up with 13.791111 × 3.5=48.2 cars (50 cars approx.)

Fig 2 shows the camera position on the traffic signal. The height of camera placement should not be greater than 25 feet otherwise the system will give incorrect results in the vehicle detection process. It should be placed in such a region where any kind of obstacle must not come in front of it.

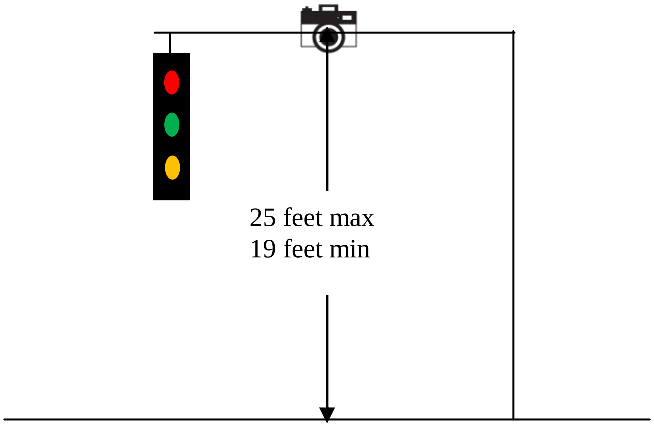

Fig. 2. Appropriate Height for Camera Placement

2) Vehicles Detection Algorithm

Here first the vehicles are detected by some car models in xml file. By using Cascade Classifier, we have created haar_cascade. It was trained in that xml file with some rickshaw model. Then with the help of Background Subtraction and BGS Library, we have subtracted the images shadow and the image background from the image. Blob detection technique is also used for better detection. We have also filtered the video frames by circularity, area inertia and convexity.

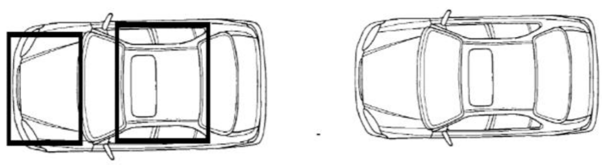

Fig. 3.Vehicles Detection Process

Light is an important factor for vehicle detection, without enough light, System will not be able to detect vehicle. During daytime light is not a problem in a sunny day but at night, it is a big challenge for the system. That is simply because the car images had not trained at night. The positive image that was provided to train the haar_casscade was just images in broad daylight. Camera should be placed in such a place where street light posts are enough for the system so that vehicles of the roads can be easily visible at night. Infrared Camera or Thermal camera can be placed for those streets where there is not much street light post, but detection procedure will be different in that case and efficiency can be decreased up to 50%.

B. Vehicle Counting Procedure

This system will analyse the video and count number of the vehicle. Vehicle counting is very important for the system, Efficiency of the total System depend on the proper and correct vehicle counting. Without proper vehicle counting, intelligent system will not be able to take correct decision for traffic light control management. Proposed vehicle counting system uses multiple reference lines to count vehicles. Every reference line is a pixel coordinate in video frame, which builds an area of interest for vehicles. When a vehicle crosses the first reference line, a counter element is increased by one in its area and when the same vehicle crosses the second reference line, it decreases the counter. A control system analyses the counter element and calculates the number of active vehicles in a particular area. These analysis helps control system to make correct decisions for the traffic signals.

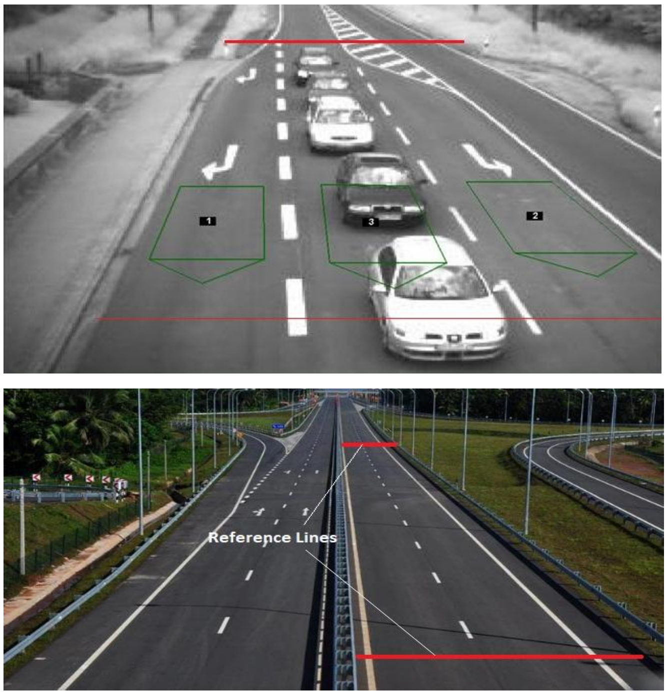

Fig. 4. Vehicle Counting Using Multi Reference Line Technique.

There can be a limit of counting vehicles for a segment of road and that will be given by the traffic monitoring system administrator (TMSA).When the given amount of vehicles is detected which are stationary because of congestion, it will prompt a message to the system. Finally, it makes the decision after calculating the jam situation. All cameras will send its data to the main computer and the computer will process these data as shown in the proposed model.

C. Proposed Model

Proposed system is a synchronised intelligent traffic signal monitoring which is an improved way of traffic monitoring and it enhances the way we are dealing with other problems and the situations related to transportation. The proposed model introduces two different components. First, a monitoring system, second control system.
Both components are able to integrate together and use data of the same directional backwards-forward signals simultaneously to take intelligent decisions efficiently. Fig 5 shows the proposed model.

Monitoring system components have been designed to perform different tasks to give efficient results. These components are used to detect vehicle, vehicle counting, vehicle type identification and data synchronization. However, every component has individual work but some important data sharing is done between them to take better decisions for controlling component.

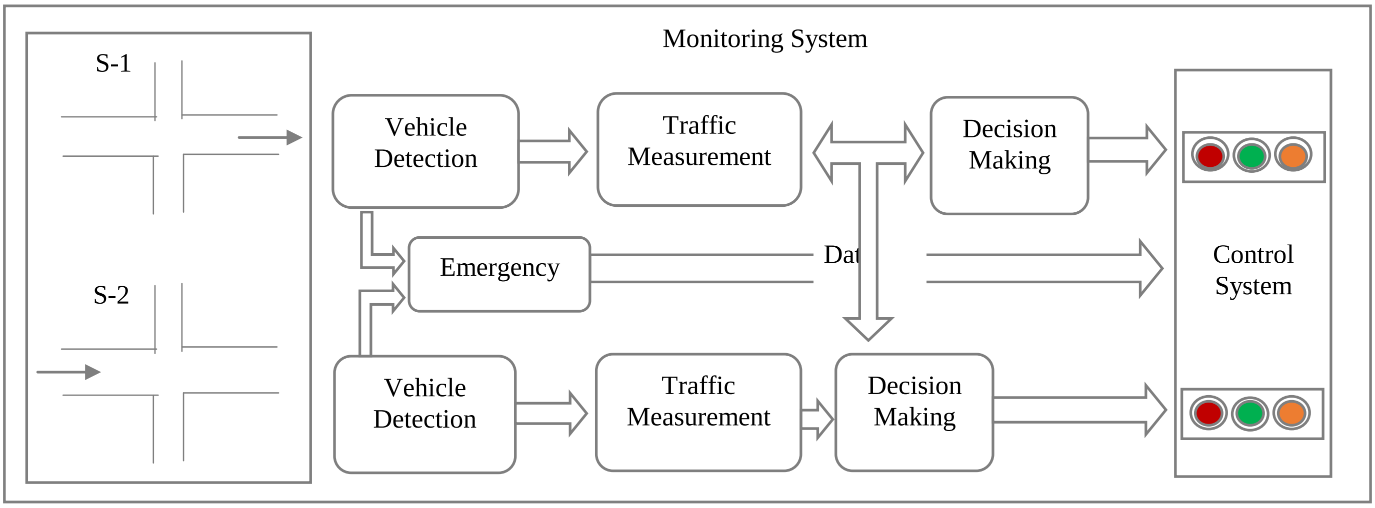

Fig. 5.Proposed Model

In our proposed model S-1 and S-2 are the two sequential traffic signals on which two monitoring systems are working together. Some key points in monitoring system components are as follows.

- The system gets input from the traffic camera and uses it to detect the vehicle in the vehicle detection component. This component uses different algorithms and techniques to detect vehicle which we have been discussed before.
- In the vehicle detection process, labels are generated for each detected vehicle. if the system detects an ambulance label for any vehicle then the system sends an instruction to the control system directly as an emergency.
- Traffic measurement component is totally dependent on the previous component. It uses multiple reference lines with specific coordinates of video frames that calculate vehicle congestion by line crossings. When a detected vehicle crosses the first reference line it increases the vehicle count in its counter of that side and when it moves out from second line counter decreases.
- After traffic measurement of each side, the monitoring system performs two tasks simultaneously; first, it shares its measurement data to the next same directional signal monitoring system. Second, send instructions to the next component to make decisions for the current signal.
- In the process of decision making, the system analyses congestion in each direction and sends instructions to the control system accordingly.
- There is a mechanism in the decision-making process which works differently on each same directional signals because it also uses data of the previous signal to make decisions.

Control system changes the signals according to instructions received by the monitoring system. If an emergency instruction is received, the control system changes the corresponding signal immediately with blocking other signals. In case of emergency, the system skips traffic measurement and decision-making processes.

D. Proposed Algorithm

Proposed algorithm shows the overall process of proposed traffic monitoring system.

1. Train the system using sample images
2. Apply trained model
3. Input: camera footage
4. Create reference lines r1,r2 on the view
5. Detect vehicle, plot frame f on detection
6. If f.bottom > r1 increase vehicle counter
7. If f.bottom > r2 decrease vehicle counter
8. Do 6, 7 on each signal & direction s1->left=right, top= bottom & s2-> left=right, top= bottom.
9. If emergency==true for any direction (left, top, right, bottom) turn Green corresponding direction.
10. If s1.left.counter > s1.top.counter then

11. s1.left = Green & s1.top = Red
12. sync s1 data to s2
13. If s2.left.counter > s2.top.counter then
14. s2.left = Green & s2.top = Red
15. If s2.left.counter < s2.top.counter & s1.left.counter > s2.top.counter then
16. s2.left = Green & s2.top = Red else
17. s2.left = Red & s2.top = Green
18. Go to 3

V. RESULTS

Fig 6 shows the vehicle detection and counting in a sample footage used for testing the detection and counting efficiency. In this sample footage, we found, the system detected a white car with 89% prediction whose direction is down and speed is 45 km/h.

Fig. 6.Vehicle Detection and Counting

There are two reference line in the footage which is used to make decisions on the basis of the number of vehicles present in between them. Fig 6 shows the signal is "on" because there is one vehicle, at the same time Fig 7 shows there is no vehicle and therefore the signal is "off".

Fig. 7.Road with Zero Vehicle Detected

The results generated are collected from multiple input video samples with multiple parameters. All tests have been done on a recommended testing machine.

A. Vehicle Analysis

Table II gives the details of the vehicle count, speed and type. This insight is being generated by the use of an input sample named "1.mp4".

Table- II: Vehicle Counting, Speed and Type Analysis

Type	Colour	Direction	Speed	Counter
Car	White	Down	45.8896086	1
Car	Black	Down	61.08	2
Car	Blue	Down	64.08913083	3

Fig 8 shows the graph of vehicle analysis.

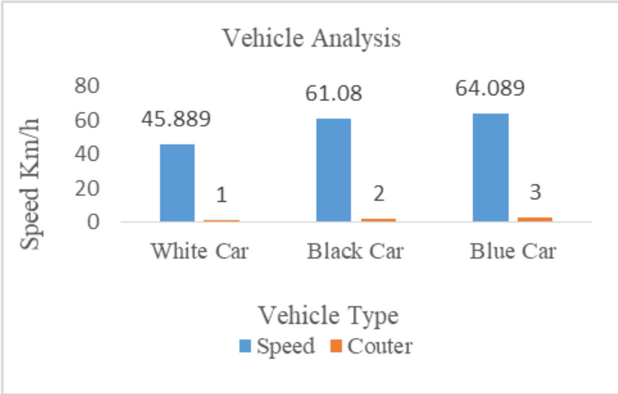

Fig. 8.Vehicle Analysis

B. Emergency Control

Table III gives emergency condition controlling details with vehicle detection as type ambulance (emergency) and changes signal state accordingly.

Table- III: Emergency Condition Controlling

Signals Direction	Number of Vehicles	Emergency Detected	Previous State	Current State
⇨	5	No	On	Off
⇦	10	No	On	Off
⇧	3	Yes	Off	On
⇩	5	No	Off	On

Fig 9 shows emergency controlling system on a single signal according to numbers of vehicles and vehicle type in each direction of the signal.

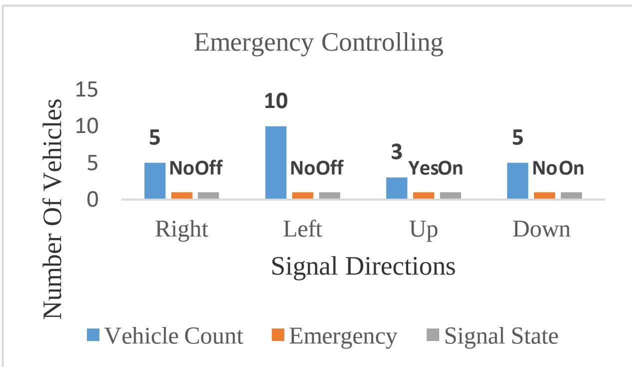

Fig. 9.Emergency Controlling

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C. Signal States with Synchronous Backward-Forward Signals

Table IV gives signal states of traffic signal and Table V gives next connected signal state without synchronous data and Table VI gives next connected signal state with data sharing between them.

Table- IV: The Signal States According to Number of Vehicles

Signals Direction	Number of Vehicles	Emergency Detected	Current Signal State
⇨	10	No	Off
⇦	5	No	Off
⇧	3	No	On
⇩	5	No	On

Table- V: Right Connected Signal States without Synchronization

Signals Direction	Number of Vehicles	Emergency Detected	Current Signal State
⇨	5	No	Off
⇦	5	No	Off
⇧	10	No	On
⇩	3	No	On

Table-VI Right Connected Signal States with Synchronous Data Sharing

Signals Direction	Number of Vehicles	Emergency Detected	Current Signal State
⇨	5	No	On
⇦	5	No	On
⇧	10	No	Off
⇩	3	No	Off

If there is no emergency, the signal will be "On" in a particular direction until the vehicle count decreases than other direction's vehicle count. However, on the connected signal, the signal state will change according to its own vehicle count and previous signals vehicle count.

VI. CONCLUSIONS

Traffic congestion has become a significant issue especially in urban areas. The most generic cause for the traffic jam in India is an incapable traffic signal monitoring system which affects the traffic flow severely. Frequent traffic jams at major urban areas always create a need for an efficient traffic management system. In this dissertation, we have successfully implemented an efficient system for a real time video processing based intelligent traffic monitoring system that detect, count, identify vehicles and make decisions to control traffic jam. Through our proposed work, we tried to show the advantages of computer vision technique of OpenCv with machine learning for an automated traffic management system. Implementation proposed work would exclude the need of traffic personnel at various areas for regulating the traffic. Moreover, we have used synchronous backwards-forward data sharing with each traffic signals that helps the system to make effective decisions for connected signals. This technique gives an extra advantage to our system. Thus, we can ensure that our proposed system will be valuable for the analysis and improvement of road traffic.

A. Limitations

- Backwards-forward synchronization of traffic data is limited to two traffic signals.
- A high-end machine is required once to perform video processing fast and efficiently.

B. Future Work

- Proposed work is a promising approach for providing the efficient and accurate decision-making traffic controllers, but need to adopt more literature for improving the technique for synchronizing all traffic signals globally by which peoples can predict traffic conditions of the particular area.
- Different machine learning or deep learning or hardware acceleration techniques may increase the performance of the system

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