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# *Smart Traffic Dynamic Manipulation System Using Vehicle Density*

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*Abstract*— **This paper proposes an improved approach to maximize the traffic flow by reducing the average queue length and average wait time. The task is performed by considering the density of vehicles present at each lane of road making it the dynamic manipulation instead of static. It uses image processing and object detection to identify the density of vehicles. Emergency vehicles like ambulance, fire trucks will be detected so that the particular lane will be given a green signal until the emergency vehicle is passed for higher preference over others. Also, the backup for failure of the live detection is provided by the help of machine learning model which will predict the density as per training.**

Keywords: Vehicle Density, Emergency Vehicle, Dynamic Manipulation, Cycle pattern, Minimum Switching Time

## I. INTRODUCTION

Increase in the value of world population therefore going towards extreme use of vehicles and enhancement in the traffic volume in different regions. Road traffic jam is the major culprit for car accidents, lower speeds, longer waiting time and irritation. Traffic congestion is the main reason detected. The traffic congestion pattern requires studying carefully in order to ensure smooth conduction. The smooth conduction of traffic will result in many advantages necessary for the society.

### *A.* Traditional Management of Traffic

1. Controller System

In traditional system a traffic signal is typically controlled by a controller mounted inside a cabinet it uses the concept of phases which is group of roads which does not have conflicts. The algorithm that is use here is static in nature and does not consider the dynamic nature of traffic but it ensures that the signal should be manage so that there is green signal continuously on the straight road, zero conflicts among various junctions of road. The major disadvantage of the present system is unnecessary time of each road side that is for each road side time for green signal is fixed no matter how many vehicles present at road the signal will not switch the state until the time completes. The above scenario creates unnecessary load on road side with the high traffic flow and creates vehicle congestion.

2. Fixed Time Control

The controller is assigned with the algorithm which has fixed time plans for the road junction and repeats it in the cycles throughout day. The fixed timings of the cycles result in various problems such as congestion on the side with more vehicles, extra time for the side with few vehicles. These repetitive cycles are the major issue since they are not considering the condition of the road junction also count of vehicles on each road side. This results in the improper manipulation of the traffic because current system is not considering the present situation for controlling the signal instead it is just repeatedly switching between signals for fixed time span.

### *B.* Major Problems

1. Traffic congestion

It is the condition which results in slower speeds, longer travel time and increased vehicle queuing. Traffic congestion has become problematic since 1950s [13]. The major negative impacts are wasting time of passengers reduces economic growth, delay result into late arrival for employment, failure of the systems forecasting travel time frustrating people, increase in the fuel wastages causing more and more air pollution and carbon dioxide emission, wear and tear of vehicles due to frequent acceleration and braking causing continuous replacement and repair, increasing road rage. As it is a serious issue and impacts lot of things the consideration of it should be on priority basis.

2. Time

Traffic signals are fixed for predefine timings and are not capable of identifying road density. This causes the roads to have same time irrespective of the vehicle density resulting in longer waiting time. Time plays very important role let us understand this with a scenario suppose at any 4 road junction

the time assign for one road is 20 seconds for green signal but in 10 seconds all the vehicles passed and the road become empty still signal continues to be green for next 10 seconds as time is fixed for each side and this results in other vehicles waiting for longer time. Now if this thing happens several times in a day it will add up to large amount of time to get wasted.

3. Handling emergency vehicle

The current system does not account emergency vehicles separately and hence there is no provision for them. The damage cause in case of accidents or attacks depend on the effective response of emergency services. The emergency vehicle always should be given highest priority over any other vehicle but our current system not at all handling the case of emergency vehicle since there is no such provision for controlling signals dynamically.

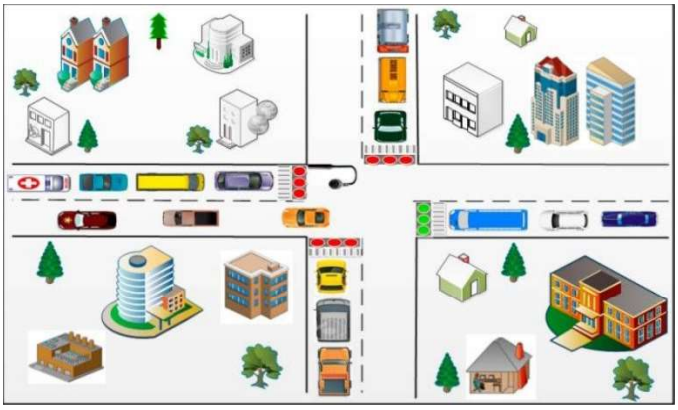

Fig 1: Figure depicting an emergency vehicle stuck in traffic [16].

In Ireland, an average of 700 fatalities was noted every year due to late ambulance responses [15].

4. Cost

"Traffic congestion costs four major Indian cities Rs. 1.5 trillion a year also commuters spent one-and-half times longer to travel a given distance at peak hours" [12]. Above statement says it all that how much traffic problem costing us though it is statistics of only four major cities in India considering overall cost in country and also in whole world would surely trouble us. The transportation is the major pillar of our economic system which has not only the direct but also many indirect impacts on the economy. The delays in transportation result in inflation due high fares, high fuel consumption and wear and tear of vehicle. Therefore, managing traffic will also result in building strong economy.

5. Impact on the Environment

The vehicles emit a lot of gases which are harmful to the environment below details illustrate the condition.
The traffic emissions is categorised as following in [14] –

- Hot emission
- Cold start excess emission
- Lube oil emission
- Air conditioning emission.

| Road | Sector | Kilometric position | Sector limits | | Sector length [km] | CO [t] | CO2 [t] | FC [t] | NOx [t] | PM [t] |
|---|---|---|---|---|---|---|---|---|---|---|
| DN 28 | Sec. 1 | 7.100 | 0.000 | 17.820 | 17.820 | 0.35 | 51.65 | 16.49 | 0.33 | 0.01 |
| | Sec. 2 | 19.030 | 17.820 | 26.350 | 8.530 | 0.19 | 26.43 | 8.45 | 0.17 | 0.01 |
| | Sec. 3 | 29.500 | 26.350 | 48.800 | 22.450 | 0.94 | 116.78 | 37.38 | 0.69 | 0.03 |
| | Sec. 4 | 57.720 | 48.800 | 65.150 | 16.350 | 0.81 | 101.44 | 32.48 | 0.59 | 0.02 |
| | Sec. 5 | 65.360 | 65.150 | 75.797 | 10.647 | 0.81 | 88.27 | 28.31 | 0.46 | 0.02 |
| | Sec. 6 | 81.250 | 80.600 | 101.835 | 21.235 | 0.66 | 82.53 | 26.42 | 0.50 | 0.02 |
| | Sec. 7 | 115.350 | 101.835 | 117.900 | 16.065 | 0.11 | 12.11 | 3.88 | 0.06 | 0.00 |
| | Sec. 8 | 118.300 | 117.900 | 141.410 | 23.510 | 0.10 | 11.33 | 3.63 | 0.06 | 0.06 |

Table 1: Table depicting the number of harmful gases emitted into the environment on a particular road in a day [14].

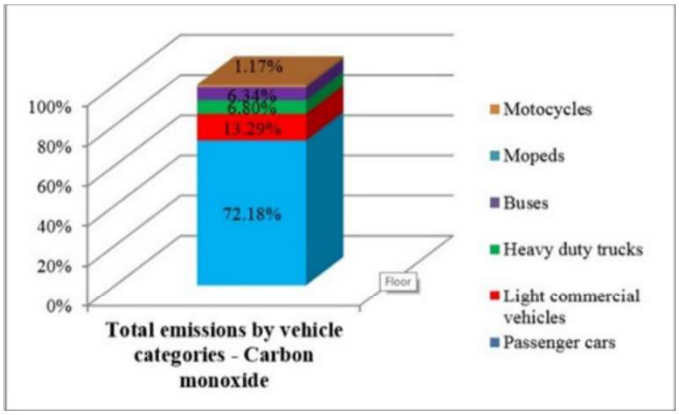


Fig 2: Total Carbon Monoxide emitted by vehicle category [14].

The conclusions from Figure 2 ensures that maximum pollution from the carbon monoxide (CO) which causes an increase in global warming is by the passenger cars (72.18 % out of total emissions).

*C.* Smart Traffic Management

1. Vehicle Density

The density (number) of vehicles on each road must be considered before manipulating it. It will bring the dynamism in the traffic manipulation, proper understanding of the traffic flow and enable us to have proper algorithms to manage the traffic.

2. Dynamic Algorithm

The management should be based on the dynamic manipulation algorithm which considers the density. The dynamic algorithm has become the necessity. Also involving such algorithms will enable the developers to develop more accurate and secure system.

3. Emergency vehicle

The emergency vehicles must be given a highest preference over others so that they can pass easily. The

importance of emergency vehicle is huge and consider them separately and have provisions that will make sure that these vehicles never suffer.

Indeed, the advancements in the technology have made system more powerful and intelligent. Also, the internet speed has grown immensely making possible the data transfer at very high rate. This paper attempts to be the possible solution for this problem of traffic management.

## REVIEW OF LITERATURE

Traffic congestion is a problem all the country especially in metropolitan cities. With the rise in population and decrease in cost of vehicles, the numbers of vehicles seen on the road are also increasing. To combat the problem of traffic various solutions have been tried and tested, with all showing different results. Various different technologies and hardware have been used to solve the problem of traffic. As traffic is one of the reasons resources like fuel, electricity and also people's time gets wasted, it is important to that officials do something to limit traffic congestion in areas that experience traffic jams all the time. Moreover, emergency vehicles like ambulance, fire brigade, police vehicle would also get in traffic jams causing them a delay to reach their destinations.

Some of the earliest solutions have been dependent on sensors like RFID [8] to let the traffic controller know position of these emergency vehicles. An RFID tag had been fit on windshield on emergency vehicles and when the receiver, fit on the traffic signal, detects such an RFID tag system notifies traffic controller about presence of emergency vehicle on that particular lane. In [11] emergency vehicles had been given an application where the driver can enter the alert level, source and destination. The local traffic controller accepted this request and planned an efficient route from source to destination avoiding traffic. Both these solution does not do anything to decrease the amount of traffic on the roads and required manual monitoring of the system. In one of the recent solutions to handle emergency vehicles stuck in traffic, [17] shows an IoT based solution where the emergency interacts with other vehicles and infrastructure through V2V and V2I. Vehicles had been fit with On-Board Units (OBU) and Roadside Units (RSU) were stationed on regular intervals on roads. These RSU sensed how many vehicles are on that road and would alert an emergency vehicle on which route to take. Although a good idea, this solution would be expensive and difficult to implement.

To ease the problem created due to traffic, cameras deployed on traffic signals were used. These cameras were used to calculate density of vehicles in all lanes. Using these densities an automated system would manage the traffic and limit the congestion by giving preference to those lanes with high traffic. Many methods were used to find density of vehicles. In [9] and [10] stills of a populated lane had been compared with images of same empty road to give an estimate of number of vehicles in that lanes. These solutions gave insufficient accuracies and could not be used in real life scenarios.

Many image processing and machine learning algorithms were also used to detect vehicles and find densities. [1] and [3] used Gaussian mixture model along with blob detection to identify and detect vehicles in an image in real time. [2] and [4] used neural networks to detect vehicles. These neural networks were trained on a large dataset of different vehicles in various angles, and then the image of the traffic lane was given to the NN, who estimated the density.

Many such approaches to solution for traffic congestion can be compared and discussed, where each of them had their advantages and disadvantages. Sensor based and camera-based approaches were better as they required minimal human interaction and therefore decreased chances of human error, but they had to be relied upon electronic devices. Density based approaches were beneficial than other approaches as they are less expensive and easier to implement. It could be concluded that Mask RCNN algorithm has the most advantages over other approaches- it is faster, easy to implement, operable in all weather conditions and can effectively manage timers on signals saving people resources.

One such algorithm used for vehicle detection is Mask RCNN, which is a neural network along with features like Residual Network (ResNet) and Region of Interest Align (ROIAlign). Most popular current object detection algorithm includes RCNN, Fast RCNN, SSD. However, these designed models need large amounts of data for training, which will not help to achieve end-to-end detection. Residual Network, with the help of residual module, makes the model to fast by accelerating training process of the neural network model. This module also then combines together with the Mask RCNN target detection model to get the object detection and segmentation. When compared with other traditional detection methods, Mask RCNN [6] not only provides a vast improvement in the accuracy for detection, but is also successful in small target detection. The various algorithms are there which can be used for vehicle detection. Figure 3 shows the statistics of comparison.

| Model | PASCAL VOC 2007 | PASCAL VOC 2010 | PASCAL VOC 2012 | COCO 2015 (IoU=0.5) | COCO 2015 (IoU=0.75) | COCO 2015 (Official Metric) | COCO 2016 (IoU=0.5) | COCO 2016 (IoU=0.75) | COCO 2016 (Official Metric) | Real Time Speed |
|---|---|---|---|---|---|---|---|---|---|---|
| R-CNN | x | 62.40% | x | x | x | x | x | x | x | No |
| Fast R-CNN | 70.00% | 68.80% | 68.40% | x | x | x | x | x | x | No |
| Faster R-CNN | 78.80% | x | 75.90% | x | x | x | x | x | x | No |
| R-FCN | 82.00% | x | x | 53.20% | x | 31.50% | x | x | x | No |
| YOLO | 63.70% | x | 57.90% | x | x | x | x | x | x | Yes |
| SSD | 83.20% | x | 82.20% | 49% | 30.30% | 31.50% | x | x | x | No |
| YOLOv2 | 78.60% | x | x | 44% | 19.20% | 21.60% | x | x | x | Yes |
| NASNet | x | x | x | 43.10% | x | x | x | x | x | No |
| Mask R-CNN | x | x | x | x | x | x | 62.30% | 43.30% | 39.80% | No |

Fig 3: Comparative study of different object detection algorithms.

In our solution, CCTV cameras are deployed. These cameras will count the number of vehicles on each lane of the road. The counts of vehicles at an hourly interval is recorded and

stored on a cloud. This traffic density statistics are fed to a specially designed algorithm to determine timings of timers on traffic lights. Mask RCNN algorithm was decided to use after going through various research papers as it gave excellent results when compared to other similar algorithms. The algorithm will dynamically allot timer values.

The algorithm with the help of the RCNN models and object detection APIs will identify and provide the dynamic signal timings based on vehicle density. Mask R-CNN is different and better than Faster R-CNN. The former does the task of predicting an object mask in parallel with predicting the bounding box for the object, hence making it faster. Comparing Mask R-CNN with other object detection algorithms such as different versions of YOLO and CNN, found that Mask R-CNN is the best performing model on COCO dataset 2016, which was an official metric.

## II. PROPOSED DESIGN APPROACH

The approach suggested in this paper focuses on monitoring traffic density by capturing the video feeds of the roads of junction in real time and using that captured video to find out the vehicle density on the road which results in the smart management of the traffic.

### *A. Methodology*

The proposed approach is to focus on monitoring the traffic density through camera by grabbing video feed of the junction in real time and then analysing the feed to extract meaningful information. The server is also sent with the calculated data which also can be remotely monitored and controlled.

### *B.* Data Gathering

The data to be gathered here is aimed to be collected from the CCTV cameras which will be available onto each road of each junction. The data will be collected as a seamless video stream and will be transmitted to the server where the processing of the data and decision making will take place.

### *C.* Data Processing

Once the data is received at the server end, the system will begin the data processing. This data processing phase will consist of data processing and then processing the normalised data to avoid any exceptions or errors. The video stream after pre-processing will be made subject to a region of interest. This region of interest will denote the area of video that will be considered while the algorithm counts the density of the vehicle.. This region of interest will be small portion of the video feed that will be considered to make the density calculations.

### *D.* Density Calculation

The density of the vehicle is the number of vehicles detected per region of interest, where the region of interest will be of same size for each of the road in the junction. The vehicles will be detected from each of the region of interest from the video feeds using the finalized algorithm. This count of vehicle will denote the vehicle density per road.

### *E.* Traffic Manipulation

The algorithm proposed in this paper will have the counts of vehicles as input per roads of the junction. This count will directly indicate the traffic conditions of each roads of the junction and will be used to rank the roads according to which road need to be signalled green first, given that no emergency vehicle is present on any of the roads of the junction. The proposed traffic management algorithm will analyse the counts of the identified vehicles of each of the roads given that there is no emergency vehicle present. After analysis of each of the roads, the proposed traffic manipulation algorithm will rank each of the roads according to their calculated traffic densities, such that the road with the highest traffic density will be signalled green. The road of the junction with highest calculated traffic density will be signalled green. To avoid starvation, each of the roads of the junction will be given a minimum sufficient timing that will be specified for each of the junctions separately. This minimum time will ensure that each of the roads of the junction will get at least the specified amount of time which in turn will ensure that none of the roads of the junction goes into starvation in the order that they were sorted based on the calculated traffic densities by the proposed traffic manipulation algorithm.

### *F.* Cycle Pattern of Algorithm

The major technique which makes the algorithm unique is the cycle pattern which is used as explained below-

The algorithm defines a particular time cycle (240 sec or 120sec depending on junction) for individual road junction. This time cycle makes sure that the starvation will not occur that is only particular road getting continuous green signal and others waiting for longer time. Inside a single cycle defined minimum switching time (Time for keeping signal green say 20 sec or 30 sec depending on junction) that too different in different cycles. The algorithm goes with defining cycle timing and then defining minimum switching time, and then the switching of green signals is done for minimum switching time for the side with highest density. The important part here is though any one road side has lowest density throughout the cycle still it will get minimum switching time at the end of cycle therefore not letting that particular side to be in starvation. The cycle definition is also dynamic depending on the time.

### *G.* System Architecture and Avoiding Delays in Data Transmission

The system architecture is shown in Figure 4 the CCTV feed is first passed on cloud before applying algorithm on it so there might be some kinds of delay due various technical reasons especially when network issue arises therefore to avoid any delays that can occur while transmission of the

video field to the cloud computing resources that host the Mask RCNN and the proposed traffic manipulation algorithm, a separate database of the traffic conditions and the signal opening times will be kept for each of the road of every junction, such that the algorithm will work on 5 second earlier video feeds and will predict the timings of each of the roads sorted by the traffic manipulation algorithm based on previously kept database using predictive machine learning algorithms.

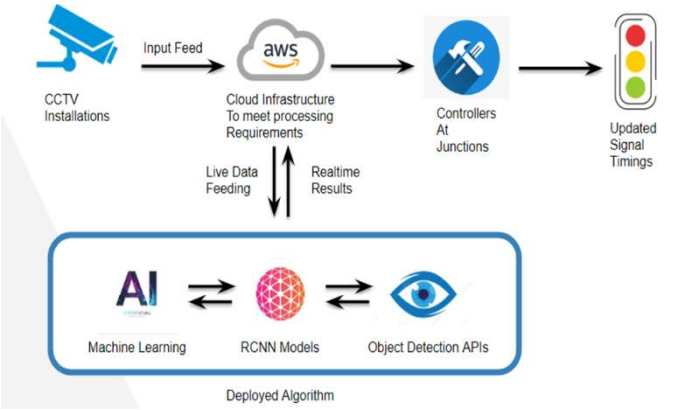


Fig 4: System Architecture

*H.* Handling Emergency Vehicles

The proposed algorithm also has been designed by keeping the emergency vehicles in mind. Suppose an emergency vehicle such as an ambulance is encountered by the Mask RCNN algorithm while processing the video feed's region of interest. The Mask RCNN algorithm then will provide the number of identified emergency vehicles to the proposed traffic manipulation algorithm. This algorithm on recognition of presence of the emergency vehicles on one of the roads of the junction will immediately give the preference to the road with the emergency vehicle and the signal related to that specific road will be turned to green to ensure the safe and efficient passage of emergency vehicles through the traffic dense junctions.

The major functions system will perform –

1. Getting the count of vehicles at each lane

2. Apply manipulation algorithm based on count

3. Consider the special case of emergency vehicle to give them the highest priority

4. If the system fails then generate the count using machine learning model train on past data.

5. Save energy by switching off system at night.

## CONCLUSION

India has a population of 1.3 billion and it is increasing day by day and the traffic system of India is not up to the mark to handle such large numbers. This surge in population causes major problems such as higher waiting times on the signals, accidents and lack of proper way for emergency vehicles. The traffic manipulation in India is done in static manner and it uses a static way to manage the traffic on the junctions. The signals in India are given a predefined counter which denotes the time in seconds the vehicles on the road will have to wait before the signal turning green. The approach presented in this paper deals with solving the traffic congestion problem by incorporating the video feed analysis. The system is expected to solve the problems caused by the still used static traffic manipulation system in India by giving a video monitoring-based solution.

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