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Dynamic Traffic Light Optimization and Control System

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Abstract

The current traffic control system is incapable since traffic signal system timers have fixed time period to switch traffic between different phases whereas traffic density pattern varies with time throughout the day. Due to which, some vehicles might have to wait for long period of time. Such situation creates heavy traffic at one side of road and other side with no traffic.To overcome this problem we have proposed a model that estimates number of vehicles, specific phase traffic area, width of road. From the above generated values we have optimized traffic signal cycle time and individual traffic signal phase time. We have used Image processing (deep learning) and Machine Learning. For image processing Viola Jones Haar Wavelet technique is used. It takes different form to construct mini classifiers to detect object differentiated by neagative and positive energies. Haar wavelet are pixel distribution that helps to classify edges in an image. Haar cascade is been used for these wavelets to overlay on the given object and create XML file to identify the vehicles and length of traffic. After that Machine learning is used to predict cycle time and allocate time to the phases of traffic signal.

Keywords: *Image processing, Traffic signal time allocation, Supervised Machine learning and Real time processing*.

1. Introduction

Current traffic control system shortfalls intelligence and act as open-loop control system with no feedback. The aim is to make current system fair, dynamic and real time. The system proposed has adaptive traffic signal timer according to the real time traffic cluster volume and vehicle number ratio along different phases. This model uses multiple cameras to sense the changes in traffic patterns around the traffic signal and does manipulate signal timer accordingly. The increase and decrease in traffic signal time directly depends on the volume of flow of traffic hitting particular signal. This change in traffic volume will affect the traffic signal timer. Henceforth vehicles face an irregular but fair delay during transit.

Our proposed system working sequence is

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(i) Real time image generation from the video format data collected from the cameras installed.

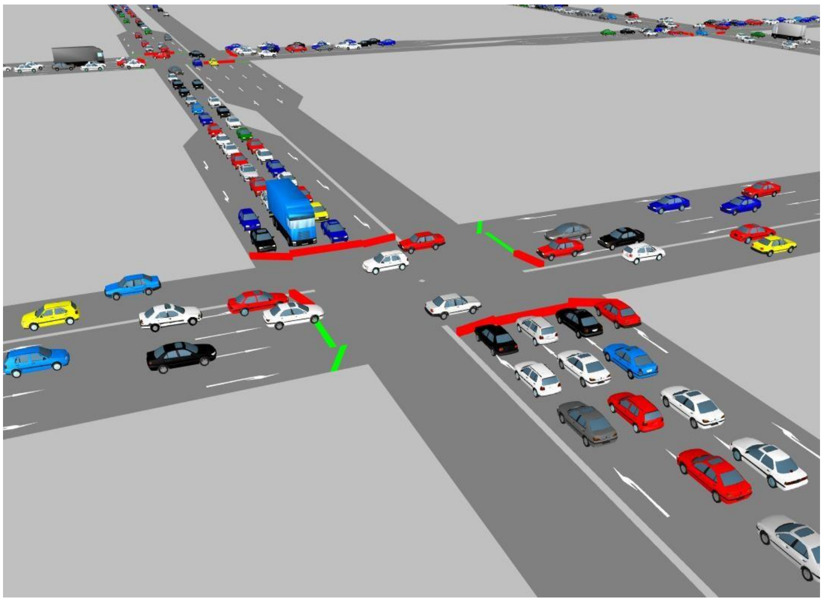

Figure 1 : Traffic Senario

(ii) Image processing using Vilola-Jones object detection framework. Output of image processing is traffic length, width, vehicle cluster area and traffic volume density. Output holds numerical values.
(iii) Individual phase time allocation and phase sequencing of traffic light signal based on Supervised Machine Learning and Features Weighing Model of Machine Learning. For the sequencing and time allocation, system uses traffic length, width of phase of road, traffic area and traffic volume density as an input.
Control of traffic system during emergency vehicle transit is also important. Using sound sensor presence of emergency vehicle and its phase of approaching traffic square can be detected. After detection of emergency vehicle a GREEN SIGNAL STATE will be allocated to the phase where emergency vehicle is detected. After transit of emergency vehicle system will be back to normal state.
Dynamic traffic signal system brings fairness. It reduces waiting time of vehicles, increases number of vehicles passing by traffic square. As more and more vehicles are hitting road, implementation of cost effective traffic signal system is need of time.

2. Related Work

Dynamic Traffic control using Artificial Intelligence and machine Learning, especially reinforcement learning (RL), has been active field of research for the past 20 years. In 1994, [1] proposed distributed reinforcement learning system using Genetic Algorithm to present a traffic control scheme that increases throughput of road network very effectively, but due to limitations of computational power it was not be implemented at that time.

On the other hand several methods have been proposed for floating vehicle data gathering from Global position system (GPS). In [2] the data is used to detect, estimate

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and predict traffic states based on Support Vector Machine (SVM), Genetic Algorithm, fuzzy logic and other learning algorithms and show it is possible to optimize traffic control based on partially observed data.

In [3] Very few systems are currently available which uses partial detection technique. COLOMBO is one ofthe projects in Europe that focuses on low-penetration rate of DSRC-equipped vehicles.

In [4], The system uses information provided by the V2X technology and provide generated data to a traffic management system. Since COLOMBO cannot directly react to real-time traffic flow, under low to medium car flow it does not achieve optimum performance as the optimal strategy under low-to-medium car flow has to react according to detected car arrivals.

The paper [5] suggested traffic light control system based on vehicle traffic density calculation. According to [5] time allocation of traffic signal system need be proportional to the traffic density of the lane. A method proposed was processing of image captured by video camera sensor and estimation of traffic density value and proportion. Depending on the traffic density time allocation is done.

In [6] another technique was proposed. In this the system comprised two models, the command station module and signal pole module. The signal pole module controls digital camera for image capturing and processing while command station module handles calculation of signal timings. Processing digital data from video images to detect vehicles, calculate density of traffic using image processing. Using this data to allocate more green light to roads with heavier traffic.

Later in [7] developed a method to track vehicle. Background subtraction and mean shift tracking are
used to track vehicles. The whole monitoring process is as following. Firstly, secondary selected strategy is used to construct background model. Then vehicle tracking objects are built at the trigger area of detection by the background subtraction. Finally, the mean shift algorithm is utilized to track vehicles. The secondary selected strategy is a new algorithm designed in this article.

Another technique was based on real time traffic light control using image processing [8]. In that, they have defined three different phases. In first phase, image of road is captured with no traffic. Firstly RGB to gray scale conversion is done on this image and then by using prewitt edge detection operator, edge detection is done and set it as reference image. Again the images of road are captured and in sequence, the RGB to gray scale conversion and edge detection is done on each images. Now these real time images are compared with the reference image and on the set boundary of matching percentage, the time is allocated.

3. Proposed Methodology

A complete system is of four modules: Timely image extraction, Image processing, Traffic signal phase time allocation and emergency system design.

A. Timely Image Extraction

A data available is in video format. Videos are captured by cameras installed at traffic squares. Video processing is not efficient and not practical. Video processing is time taking, costly and does require advanced technology. It is more convenient to extract images from available video data at real time. A system is programmed so that it extracts image after certain constant time period. For the traffic signal system cycle, during the

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period of RED LIGHT STATE of X seconds, after fixed defined time image is extracted from the video data and also just before the start of GREEN SIGNAL STATE an image captured. Timely Image generation Algorithm :

```
Timely_image_generation ( )
Timely-image-generation ()
{
from the video data of most recent previous cycle

    for ( phase 1,2...n)
    {
     if(signal is RED)
      {
        Capture image IMG after every n seconds
Store IMG
       }
    }
}
```

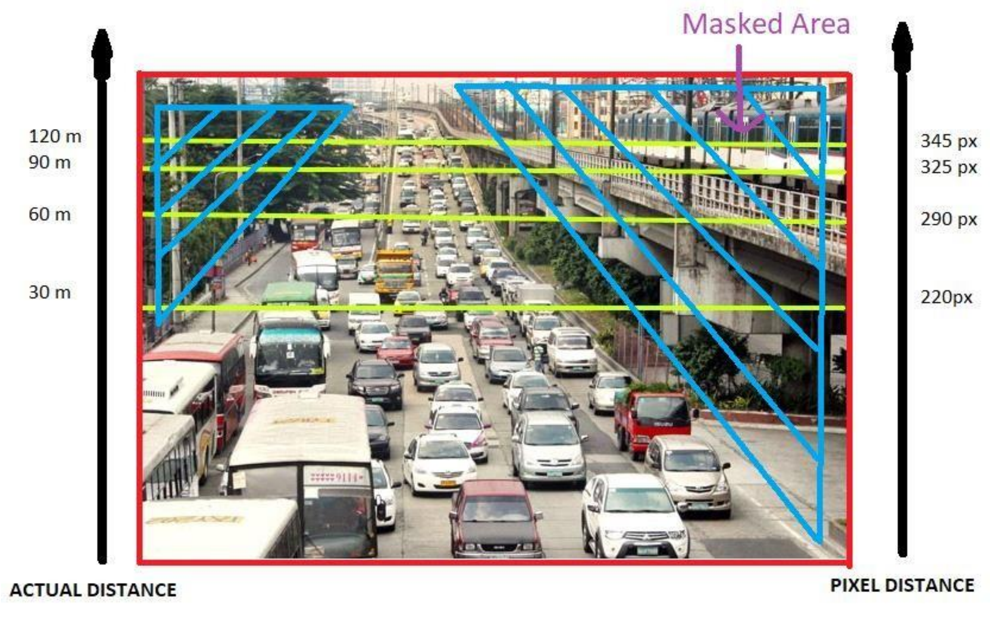

Figure 2 : Image Trimming

B. Image Processing

Extracted images are firstly examined as some part of image is not required. Part of image not required or pixels which are not necessary are cropped. Thus cropped image shows only lanes of particular phase and vehicles.
From the cropped image, multiple vehicle detection and mapping is done. All pixels of image where vehicles are detected are marked. An image with marked pixel and number vehicles detected is now taken into consideration.
As we all know in an image clicked by camera, vehicle nearer to camera takes large part of image

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than the vehicle which is away from it. Marked pixels images cannot be used to generate traffic queue length, road width, traffic cluster area and vehicle density values. Optimized top view of vehicle traffic phase is generated from the image (marked with pixel values).
Optimized top view image is black-white image where black color indicates vehicle covered area. From the top view image vehicle traffic queue length, road width, traffic area and traffic density values are estimated.

Image Processing Algorithm :

```
Image-cropping ( )
{
Crop image
}

image-process ( )
{
Generate
W = road width
Q = vehicle traffic queue length
N = Total vehicles detected
Calculate from (W,Q,N)
D = Traffic density
A = Traffic cluster area
}
```

Figure 3 : Image Detection

C. Traffic Cluster Volume Estimation and Signal Phase Time Allocation

We have used Supervised Machine Learning and Features Weighing Model of Machine Learning for the time allocation of the traffic signal phase. Output data of image processing that is traffic length, road width, traffic area and density are the input features to decide the time of GREEN signal state of each phase. Mentioned features values and respective weights assigned will generate numeric value, what we call Traffic volume. Based on the estimated traffic volume value, time is allocated to each phase. Here traffic

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volume value and time allocated to phase are directly proportional. After every cycle 10 seconds time period is allocated to the pedestrians.

Phase Time Allocation Algorithm :

```
Traffic-cluster-volume-estimation( )
{
for( each phase 1,2.......n)
{
calculate-cluster-volume(Q,W,D,A,N)
{
CV = summation (Weight* value)/ summation weight.
} } }
Time-allocation()
{
Total cluster volume TCV sum of CV of all phases
P = (CV / TCV) *(Total traffic cycle time)
}
Where P is particular phase Green State time.
```

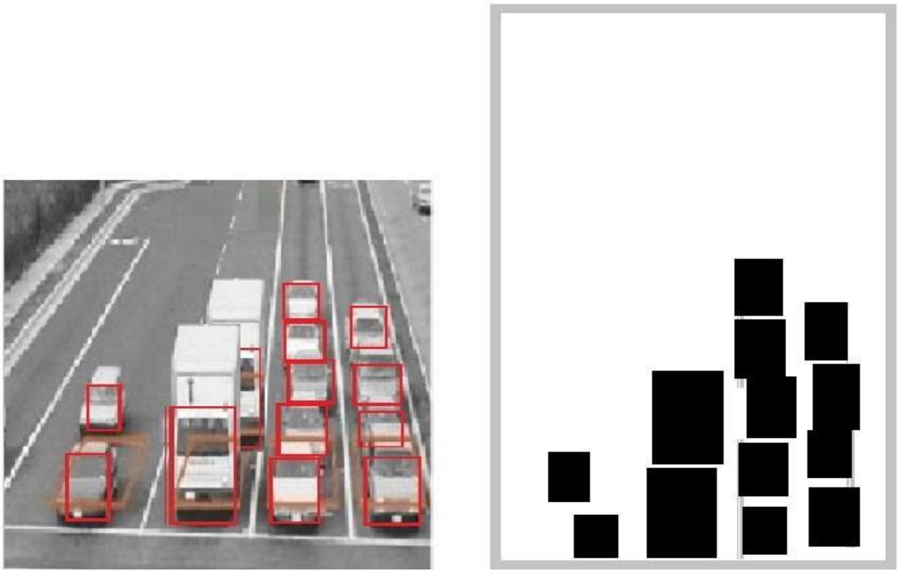

Figure 4 : Image Trimming

D. Emergency System

It is necessary to assure easy transit of emergency vehicles like ambulance, Fire brigade vehicle. These vehicles must not get stuck in traffic. Sound sensors are used to detect emergency vehicle and its phase. Whenever sound sensor detects emergency vehicle sound and its phase, video of that phase is generated. After video analysis emergency vehicle is verification take place. Particular phase is assigned with GREEN SIGNAL STATE. After video processing system confirms emergency vehicle is passed, normal traffic signal system starts again.

5. System Design

Model includes system model with some definitions and assumptions. Assume a single

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intersection at an urban area with traffic camera installed to it providing clear image of the traffic.

The whole software consist of two phases i.e. image analysis followed by machine learning to generate
sequence and time allocated to each traffic light at the intersection. Image analysis is done on images
provided by each direction of lane on the particular intersection. For the purpose program on (python 3.6.2
using Open CV library) and vehicle detection libraries for the purpose of getting vehicle count, length, road width , traffic spread on road and finally their density. The vehicle detection system requires several images which include vehicle and have minimal background variation. OpenCV library allows the system to easily identify vehicle on road and provide vehicle count for further processing.

Haar feature are used to detect road edges and crop out road section to get a well defined image of working
area. Thus providing the system the two major variable i.e. vehicle count and road area.
These two variable
will be processed in each image to calculate the vehicle density which will be final measure for sequencing and time allocation of traffic light. This data is forwarded to ML module for calculation and predictions.

Image acquisition :Image acquisition in image processing generally defined as the action of retrieving an image from specified source, usually a hardware-based source, so it is passed through whatever processes that need to be occured afterward. Performing the image acquisition in processing of an image is always the initial step in the workflow sequence because, without an image, no processing is possible. One of the ultimate goals of image acquisition in processing of image is to have a input source that does operate within those controlled and guidelines which were measured so that the same image can, if necessary, be nearly perfectly reproduced under the same conditions so anomalous factors are more easy to specifically locate and eliminate. Image should be captured while vehicles are at reduced the speed, as fast moving vehicles cannot be captured using cameras.
Image enhancement :Image Enhancement involves the modification of digital data for improvisation of the image quality with the help of computer. The processing does also help in clarity maximization, sharpness and details of features of interest towards information extraction and furthermore analysis. The principal objective of enhancement is to process an image so that the result is more suitable than the original image for a specific application. Due to road pollution, wind, and camera's heavy shutter, the captured image might not be good and may not be suitable for further processing, so the captured image should be enhanced before passing that image to the next module. feature extraction: It starts from an initial set of measured data and build derived values intended to be non-redundant and informative, facilitating the subsequent learning and generalization steps, and in some cases leading to better human interpretations. Feature extraction is related dimensionality reduction.

The Canny Edge Detection Algorithm.
1) Smoothing of an image: Blurring image for noise reduction.
2) Finding Gradients: Wherever the gradients of the image has large magnitudes, the edges should be marked.
.3) Non-maximum Suppression: Only local maxima must be marked as edges.
4) Double Threshold: It applies a double threshold filter on multibeam variables for the specified data removal purpose.

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5) Hysteresis Edge Tracking: Final edges are estimated by suppressing all edges, not connected to a very certain (strong) edge.

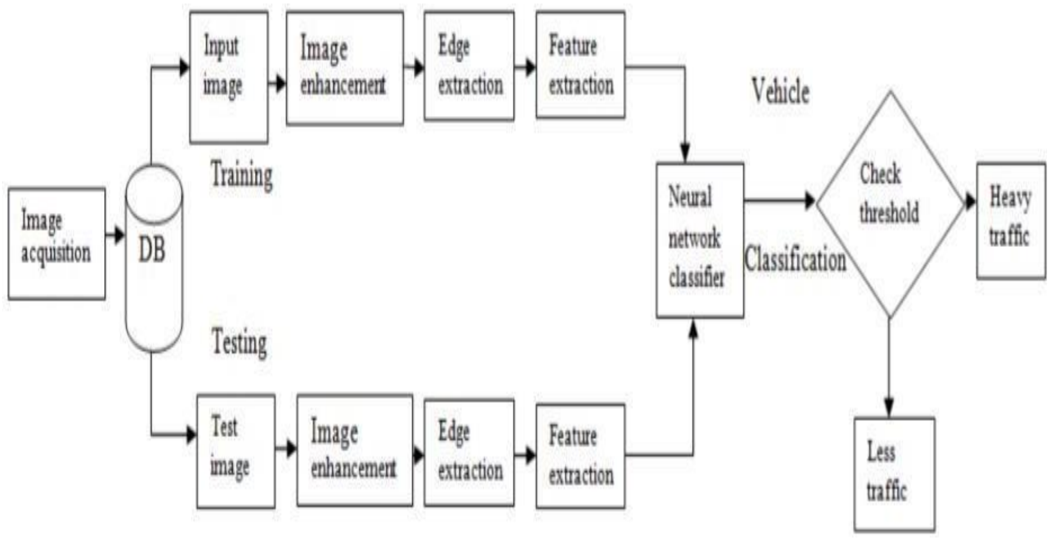

Figure 5 : Architecture

The data received by the ML module will get the value like vehicle count, density, road width ,and lane
priority. ML module will learn through supervised training via dataset provided and henceforth prediction the output at later stages which will reduce the repetitive calculation time. Every parameter used to train ML module will be provided with there own weight to provide better and desired output. For an extreme condition of traffic (very high or low density) the threshold of time allocation will be set(e.g. 10 sec for low or no traffic and 60 sec for every high density). Final output of ML module will be time provided to traffic light for each line .

4. Experimental Results

Number of vehicles detected by the system and the actual count of vehicles were as follows :

Predicted	Actual	Accuracy
67	80	83.75

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51	60	85.00
38	45	86.67
25	28	89.28
13	14	92.85
06	06	100

Thus we can say that for small number of vehicles the accuracy is high whereas for large number of vehicles accuracy decreses.

With respect to length of traffic,Time allocated is :

Traffic Length of Individual phase (in mtr)	Time Allocated to specific phase (in sec)	Length in %	Allocated time in %
22.493	43	23.21	23.88
27.632	48	28.51	26.66
33.160	62	34.22	34.44
13.546	27	13.98	15.00

5. Conclusion

The traffic congestion problem has become more serious of the potential growth of the vehicles. In this paper inspired of cost cutting, more practical and not using advanced costly technology or hardware difficult to implement. We introduce new approach for real time management of the traffic flow based on estimating the number of vehicles and time required for vehicles to pass the signal at different phases. In this regards, the time allocation and sequencing of phases of signal is done so that fairness is not compromised. Dynamic time allocation will allocate different time to each phase of traffic signal for every other cycle.

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