Smart traffic lights switching and traffic density calculation using video processing

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Anurag Kanungo

Carnegie Mellon University

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Smart Traffic Lights Switching and Traffic Density Calculation using Video Processing

Anurag Kanungo
University Institute of Engineering and Technology
Panjab University
Chandigarh, India
anuragkanungo@gmail.com

Ayush Sharma, Chetan Singla
University Institute of Engineering and Technology
Panjab University
Chandigarh, India
mailayush604@gmail.com
chetanksingla@gmail.com

***Abstract*—Congestion in traffic is a serious problem nowadays. Although it seems to pervade everywhere, mega cities are the ones most affected by it. And it's ever increasing nature makes it imperative to know the road traffic density in real time for better signal control and effective traffic management. There can be different causes of congestion in traffic like insufficient capacity, unrestrained demand, large Red Light delays etc. While insufficient capacity and unrestrained demand are somewhere interrelated, the delay of respective light is hard coded and not dependent on traffic. Therefore the need for simulating and optimizing traffic control to better accommodate this increasing demand arises. In recent years, video monitoring and surveillance systems have been widely used in traffic management for traveler's information, ramp metering and updates in real time. The traffic density estimation and vehicle classification can also be achieved using video monitoring systems. This paper presents the method to use live video feed from the cameras at traffic junctions for real time traffic density calculation using video and image processing. It also focuses on the algorithm for switching the traffic lights according to vehicle density on road, thereby aiming at reducing the traffic congestion on roads which will help lower the number of accidents. In turn it will provide safe transit to people and reduce fuel consumption and waiting time. It will also provide significant data which will help in future road planning and analysis. In further stages multiple traffic lights can be synchronized with each other with an aim of even less traffic congestion and free flow of traffic.**

***Keywords*— Hardcoded versus intelligent traffic control; Junction Traffic Simulation; Reduced Traffic Congestion; Signal Control; Switching Algorithm; Traffic Density Calculation; Video and Image Processing.**

I. INTRODUCTION

In the modern era, one of the most exigent issues that our society is facing is vehicular congestion increasing at an exponential rate. Let us take the case study of Chandigarh, one of the Union Territories of India. Chandigarh has the largest number of vehicles per capita in India. According to Chandigarh Transport Undertaking, more than 45,000 vehicles were registered this year in Chandigarh making the total count of more than 8 lakhs vehicles on the road. While the number of vehicles are increasing at a fast pace, the infrastructure in the city is not being able to match this growth. Traffic jams during rush hours are becoming a routine affair, especially in the internal sectors where long queues of vehicles can be seen stranded. Therefore, we have tried to address the problem with the help of our research paper wherein the focus would be to minimize the vehicular congestion with virtually no installation of any kind of hardware. We have achieved this with the help of video processing of the live feed that can be obtained from surveillance cameras and eventually to deploy a feedback mechanism in the working of the traffic lights where the density of the traffic would also be factored in the decision making process.

II. LITERATURE REVIEW

An excessive amount of research has been conducted to mitigate the problem of vehicular congestion.

[4] Khekare, G.S., Sakhare A.V. proposed the development of VANETs (Vehicular Ad Hoc Networks), which are the quintessential of the new types of networks emerging in the wireless technologies. The salient features of VANETs are to provide communication between vehicles themselves and between vehicles and road side units. VANET also plays an important role in concepts such as smart cities. The paper is based on a framework of a smart city that will transmit information about traffic conditions and will go a long way in aiding drivers to take spontaneous and smart decisions to prevent themselves from vehicular congestion which will ultimately help in reducing the overall congestion.

[5]Badura S., Lieskovsky A. presented a new model for intelligent traffic systems which will encapsulate the features of surveillance via the cameras present on the junction and with the help of data delivery systems let the users access that data. Image Analysis and foreground/background modeling schemes would be the important elements of Surveillance and data transmission over a mobile Ad-hoc network will comprise the data delivery part of the entire system. Various experiments have been conducted in the project and they exhibit great potential in terms of efficiency and real time execution.

[7] Salama A.S., Saleh B.K. and Eassa M.M. provide a design of an integrated intelligent system for management and controlling traffic lights with the help of Photoelectric Sensors. The installation of the sensors is a very important criteria in

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this system because the traffic management department has to monitor cars moving at a specific traffic and then to transfer this data to traffic control cabinet which can then control the traffic lights according to the sensor's readings by employing an algorithm based on the relative weight of each road. With the calculation of the relative weight of each road, the system will then open the traffic for that road which is more crowded and give it a longer time as compared to the other less congested roads. The real time decision making ability of the system stands out very saliently. Moreover, the system can also be programmed for emergency scenarios such as passing of presidents, ministries, ambulance vehicles and fire-trucks that require virtually zero congestion through an active RFID based technology. As a result the system will guarantee the fluency of traffic for such emergency cases or for the main vital streets and paths that require the fluent traffic all the time, without affecting the fluency of traffic generally at normal streets according to the time of the day and the traffic density. Also the proposed system can be tuned to run automatically without any human intervention or can be tuned to allow human intervention at certain circumstances.

[8]Haimeng Zhao, Xifeng Zheng, Weiya Liu presented a design of intelligent traffic control system based on DSP and Nios II. Their model of intelligent traffic control system deploys dual-CPU combined with the logic control of FPGA (Field Programmable Gate Array) which involves functions like cross-phase adjustment, exchanging and establishing related information and live human-computer interaction. In order to achieve vehicular congestion it is different from the conventional traffic signal controller in way that it works mostly at the mode of timing and multiple phases according to the user demands dynamically. Both the hardware and software system are realised in the paper.

The system proposed by Sakhare, Khekare [4] suffers from a limitation that to implement VANET the appropriate hardware has to be installed on every vehicle which can be comparatively difficult to install in a two-wheeler. Moreover, the entire framework is user dependent as the overall traffic congestion will depend on the decisions made by the user.

The model designed by Salama [7] requires the deployment of photoelectric sensors and by Zhao [8] requires logic control with the help of FPGA. Both these systems demand constant maintenance both in monetary terms and system analysis. All the more, they are comparatively more prone to damage due to the rugged external conditions in which are deployed.

The method proposed by us overcomes the limitations of Khekare [4] as it is implemented on a four-way junction and has no relation to every automobile that crosses it apart from its vehicle density and as the only hardware employed in our research are the surveillance cameras on the four-way junctions therefore no need of constant maintenance and less prone to failure as is the case with Salama [7] and Zhao [8].

III. Design and Methodology

A four-way junction would suffice our purpose of demonstrating the functioning of our system.

Design of the system

- Road Diagram showing live feed from cameras.
- Images showing changing density of vehicles on road.
- Algorithm providing traffic light switching and its results

Following Diagram shows the design of the system:

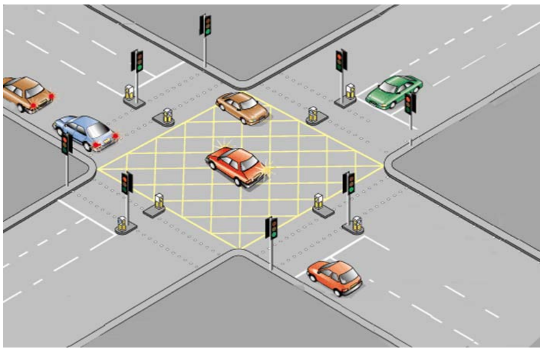


Figure 1: It is four way Junction

Figure 2: Cameras installed on red light.

Methodology

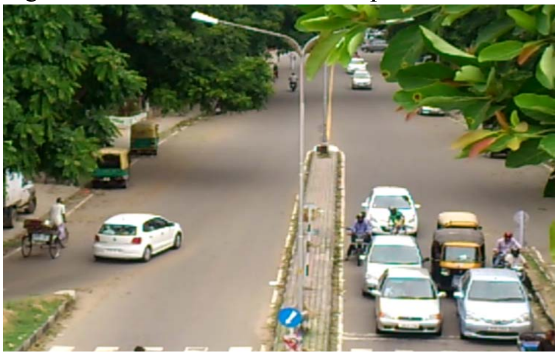
This system consists of video cameras on the traffic junctions for each side as if it is a four way junction. Therefore four video cameras will be installed over the red lights facing the road. Cameras would be capturing video and broadcasting it to the servers where using video and image processing techniques the vehicle density on every side of the road is calculated and an algorithm is employed to switch the traffic lights accordingly.

Hardware also includes connection of these cameras to the server to receive live feed and a server capable enough for handling the processing requirements.

Software used in the system includes MATLAB video and image processing toolbox [1] and C++ compiler to generate algorithmic results.

Take a four way traffic junction, having sides named S1, S2, S3 and S4. Cameras are installed over the red light for each side named C1, C2, C3 and C4 respectively. Server receives the live feed from the cameras and performs similar processing for each feed.

Figure 3: Camera feed from C1 at particular instance.



We are interested in only one side of the road so the frame is cropped to required area and is converted to black and white as shown.

Figure 4

Now we need the image of the lane when it was empty as a reference. This is done manually and required to be done only once since the same background image can be used until the structure of the road is changed.

Figure shows the background image converted to black and white for the side C1.

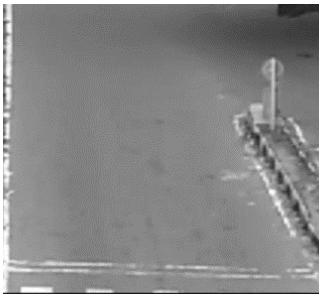


Figure 5

As video is being captured at 30 frames per second and we are looking for vehicle density every second. So let’s consider a time t, it contains frames t [1 to 30].

Now,

```
number =0;

for i=1:30
```

We use image subtraction technique. [2]

```
i= imsubtract(background,t[i])
```

After that we calculate the size of the matrix of the subtracted image we receive.

```
x=size(I);
```

In the following code we are adding up all the values present in the matrix of subtracted image.

```
for i=1:x(1)
for j=1:x(2)
number= number + (I(i,j));
end
end
end
```

So, after 30 iterations we receive a number and then the number is divided by a constant value ‘c’ which is determined as:

C= Height of camera from road * Number of rows in subtracted image matrix * Number of columns in subtracted image * Number of frames per second in video i.e.

c= h* (1)* (2)*fps

number = number/c;

This provides us with the approximate density of vehicles on road considering that a vehicle larger in size will have higher density as it will cover relatively more area and more time to pass the traffic junction. This process is repeated for every second and for all the sides.

Now, we have the real time density of vehicles at every side of traffic junction and density is added to the algorithm as a variable stated below to switch the traffic lights.

Please note that it doesn't provide the number of vehicles. It provides the density of traffic, for instance the vehicle density of a truck could be equivalent to two medium sized cars and the benefit of calculating the vehicle density is the amount of time a truck will take to pass the light which would be equivalent to the total amount of time two cars will take one after another.

Following figure shows the density of vehicles at a time.

Density scale mentioned on left side of this image.

Figure 7

IV. Simulation and Results

Hard Coded: In the conventional traffic lights after every particular time the light switches back to red. Therefore we take a scenario where it is a junction with four sides, so at any side green light remains for 60 seconds and red for 180 seconds i.e. every side gets green light for fix time of 60 seconds, one another after. This is the general algorithm of hard-coded traffic systems.

Dynamic Coded: In the algorithm proposed by us, consider a side which is currently red. On this side we will add density of vehicles present every second (It will indirectly represent waiting time), so it keeps on getting calculated for all the sides where light is red.

Now, just before 5 seconds when the green light of a lane is going to finish, we look into total density values of each lanes having red light, and the one with maximum is provided with the green signal, the density is converted to 0 for the one which was green earlier, density of other two red lights remain the same, and the process of adding up the density repeats.

The time of green signal is calculated using the number of vehicles as per density that can pass in one second. So the total density present divided by the number of vehicles that can pass in one second provides us with the amount of time for which signal is to be kept green. We will also consider that minimum amount of green light provided to a lane must be 10 sec and maximum is 60 for practical reasons.

Comparing the two algorithms:

Here we have taken into account random number for each side such as 0, 1 or 2 cars can arrive per second randomly in every lane and both the algorithms are run on the same set of numbers for 600 seconds.

Table shows the vehicle density at every lane on the interval of 30 seconds for both the algorithms which shows how many number of vehicles are waiting at every lane in a time period of 30 seconds and also the total density. In Hard coded algorithm we have assumed that lane 1 has green light from time t=0 to t=60 and they are switched after fix interval of 60 seconds. In Dynamic coded algorithm at t=0, lane 1 has green light and further lights are switched according to algorithm.

Table I

S.no	Algorithm	Time (secs)	Lane 1	Lane 2	Lane 3	Lane 4	Total
1	Hard	30	0	25	20	24	69
	Dynamic		14	1	17	6	38
2	Hard	60	1	51	28	45	125
	Dynamic		11	1	9	24	45
3	Hard	90	26	70	0	76	172
	Dynamic		8	20	2	25	55
4	Hard	120	45	85	1	91	222
	Dynamic		1	8	24	13	46
5	Hard	150	61	14	27	110	212
	Dynamic		17	0	20	8	45
6	Hard	180	77	0	50	131	258
	Dynamic		11	17	13	2	43
7	Hard	210	94	22	78	63	257
	Dynamic		1	9	20	21	51
8	Hard	240	109	43	98	3	253
	Dynamic		16	2	10	21	49
9	Hard	270	43	68	121	29	261
	Dynamic		16	24	3	17	60
10	Hard	300	1	92	152	68	313
	Dynamic		8	3	15	22	48

Both algorithms run 100 times and every time we have different set of random numbers. Here are some examples showing how many cars passed in case of both algorithms and also the improvement with the dynamic algorithm.

Table II

S.No	Total Cars	Hard Coded	Dynamic Coded	Percentage Improvement
1	571	386	475	23
2	1253	754	1077	42
3	682	429	568	33
4	491	401	463	15
5	782	523	619	18
6	931	642	811	26
7	823	511	664	30
8	1032	679	892	32
9	1126	822	935	13
10	793	560	801	43

This process is repeated 100 times and the average is calculated.

On Average Results obtained are:

Total number of cars: 870

Cars passed in Hardcoded System: 584

Cars passed in Dynamic Coded System: 805

Therefore it shows an improvement of approximately 35%.

Testing Instances and Boundations of the System:

Idle Time: Early morning 6:00 am to 8:00 am, there is a very low traffic density on the roads. Approximately one vehicle adds up in every lane per 10 seconds.

Example of Idle Time: Here we have taken into account random number for each side such as 0 or 1 cars can arrive per 10 second randomly in every lane and both the algorithms run on the same set of numbers for 600 seconds.

Table III

S.No	Total Cars	Hard Coded	Dynamic Coded	Percentage Improvement
1	117	110	112	1
2	62	62	62	0

Here we can't see any difference in the numbers of cars passed but the difference lies in the **aspect of waiting time**. In Hard Coded System a car could have to wait for 180 seconds to get the green light whereas in Dynamic, a car would have to wait a maximum of 30 seconds.

In Dynamic Algorithm considering the worst case, if a car arrives at a signal just when green light gets over, so all three signals now will get atleast 10 seconds of green and 10 seconds are enough because no lane is going to have cars greater than 10-15 during idle time and they could pass in 10 seconds easily. So, the cars which arrived just after green signal is over have to wait a maximum of 30 seconds in the worst case scenario.

Peak Time: 8:00 am to 10:00 am & 4:00 pm to 6:00 pm Density is very high on the roads majorly because of the commuters and as stated in the results Dynamic coded algorithm on average has shown an improvement of about 35% above the Hard Coded system.

Normal Time: This time the number of vehicles on road could range anywhere from very high to very low and sudden fluctuations in numbers can occur. So a Hard coded system would obviously is not desirable. A dynamic system which alters itself and switches traffic lights according to density of vehicles would be best for these conditions.

After Sunset or Low Light Conditions: Here the system doesn't work upto the expectations due to lower light conditions, in that case we could switch over system to hard coded during night time. Else we could install night vision cameras to keep the dynamic system working as it works during daytime.

Considering factors of Shadows and Weather conditions like Rain, the system won't be affected much as the effect of these conditions would be same on every side of the junction and density of every side would be affected in similar pattern. More improvements can be done with the system by using background detection techniques.

V. Conclusion and Future Prospects

The traffic management system proposed possesses certain advantages over the existing intelligent traffic control systems prevalent such as **Pressure Mats and Infrared Sensors.**

- *Installation Cost* of our system is very less comparatively because we require the live feed which is easily accessible from the surveillance cameras present at each traffic junction. Most of major cities and the traffic junction where traffic remains high have cameras already installed. So, a lot of hardware cost is cutoff, at max some cameras would require to be repositioned or adjusted.
- *Maintenance Cost* of our system is virtually negligible as our system does not include any additional hardware components as compared to the other traffic monitoring systems which employ pressure mats which normally suffer the problem of wear and tear due to their placement on roads where they are subjected to immense pressure constantly.
- *Distance among Vehicles:* One great feature is that traffic always remains at a distance. If we look at the density of vehicles at all lanes in dynamic algorithm mode and compare it to hard coded, we could see a drastic difference which would reduce congestion by almost 4 to 5 times and all vehicles can move spaciously.

This paper provides a solution to reduce traffic congestion on roads overriding the older system of hard coded lights which cause unwanted delays. Reducing congestion and waiting time will lessen the number of accidents and also reduces fuel consumption which inturn will help in controlling the air pollution. Moreover, the purview of our project can be augmented for **Coordination Control** which places traffic signals on a coordinated system so that drivers encounter long strings of green lights. This will also provide data for future road design and construction or where improvements are required and which are urgent like which junction has higher waiting times.

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