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Smart Traffic System using Traffic flow models

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1 Abstract

In today's world, one of the biggest issues faced by transportation is related to roadway traffic. While developments are focused on improving the vehicles and making them more efficient, less focus is given to improve the infrastructure and management of the traffic system on intersections like crossroads and solving the problem of traffic Congestion. The existing Systems of the traffic management system at junctions are very inefficient as traffic is static in nature. Static nature means the traffic control system/management system is independent of features that changes with time. There are some systems proposed earlier which makes the system more efficient but they are not efficient as they are not fully dynamic. The system proposed here works on the dynamic behaviour of traffic in order to reduce the traffic congestion which is dependent on real-time factors which are dynamic in nature. Another important feature is priority scheduling for Emergencies/Special Vehicles like Ambulance is also implemented. This method uses computer vision like vehicle detection and vehicle classification for implementing the same. The aim of the proposed system is to help in the reduction of traffic jamming and make the transportation time-efficient at a cost-effective implementation.

Keywords: Object detection, Traffic density, Traffic optimization, Vehicle detection

2 Introduction

Traffic Congestion is a major problem in almost every concrete jungle of the world which is inescapable. Since the vehicles are increasing day by day on roads, the facility to manage such a volume of vehicles is not improving leading to more and more congestion. The increase in this congestion leads to increase in wastage of fuel, time and energy thus increasing the overall cost of transportation [1]. Traffic Congestion occurs when the concentration of vehicles is large and the flow rate is very less which leads to traffic jams. This unavoidable problem is faced by almost every country which have other indirect problems associated with it like wastage of time and resources[2]. The major problem for this loss is because of the predefined coded traffic signal for traffic passing time. Methods have been proposed to make the management traffic, these methods are not completely dynamic and still lossy. To make traffic dynamic, the dynamic behaviour of traffic and the physics of traffic flow should be taken in consideration along with other factors like lanes of road, speed of vehicles and the specifics of the junction. The prioritization is the other part where emergency vehicles are given the preference while clearing the traffic which can be lifesaving. Thus these features should be accommodated in the traffic management system throughout the world. In the proposed method, the vehicles are detected along with the class of vehicles for prioritization of traffic. Traffic density is calculated and using other factors which should influence traffic we calculate the flow velocity of the traffic. Based on flow velocity and distance we calculate the time required to clear the traffic from a crossroad.

3 Literature Survey

There are several methods proposed to predict and describe the behavior of traffic flow and for making of smart traffic flow system. This includes a wide range of technologies ranging from camera surveillance to load cells.
A system was developed with the use of load cells, these load cells are deployed beneath the vehicles on road. This cells are to be deployed during the construction of road[3].

A smart system was introduced which involves measuring vehicle speed, traffic density, vehicle routes and pattern of traffic at different times in different routes with the help of IR led and photo detectors [4]. Some methods involved the usage of RFID Scanner and IOT devices which was used to detect traffic density[5][6][7].

Also smart traffic systems were proposed using hybrid techniques using both computer vision and RFID Technology[8].

A priority based system was also developed in which vehicles were given priority based on the class of vehicle[9]. Here vehicles are detected as well as classified into various classes like VIP Vehicles, Emergency vehicles, special vehicles and ordinary vehicles. Based on the quantity vehicles present on crossroad and type of vehicles, the traffic signal is opened or closed. For example if there is a Ambulance present waiting at crossroad and the other vehicles are ordinary vehicles, then the junction with ambulance will be opened first and the ambulance will be allowed to pass the crossroad.

A approach was proposed where traffic density was considered as time series data and was predicted using traditional time series methods[10]. Another approach was proposed where traffic was considered as time series data and was predicted using Neural Networks and LSTM cells in Neural networks[11]. However in both of the approaches, the dynamic behavior of traffic created issues, as due to some reason if suddenly traffic increases like heavy rainfall or road blockage, this models fail.

4 Proposed Methods

As seen that there are some flaws which exists in the available system and thus can't be implemented in real life scenarios. The method proposed in this paper focuses on the dynamic nature of traffic, i.e. it changes with time. The method focuses on finding the ideal time for vehicles to pass the junction. The most appropriate and efficient way to understand and formulate is using the Greensheild's algorithm where traffic was considered as a fluid. Equation(1) shows the Greensheild's equation. The results taken from real time data from survey shows the evidence shows that these models holds true in real world data[12]. Greensheild equation justified the behavior of real world traffic scenario.

$$v = v_f(1 - n/n_s) \tag{1}$$

v_f is the free velocity which means the velocity of vehicle when traffic density is zero. n_s is the saturation traffic density. It means if traffic density is beyond certain limit, the flow velocity is very low. n is the traffic density at the junction.v is the predicted speed of the vehicles given traffic density. n is the traffic density given by the image captured by camera.

There are other models available for understanding the traffic flow system which resembles more to real life scenarios. These models are Greenberg's logarithmic model[13] and Underwood's exponential model[14] which are the advance version of Greensheild equation . Equation(2) shows the Greenberg's model and Equation(3) shows Underwood's model. Greenberg's model proposed an exponential model between flow velocity and traffic density. However, main drawbacks of this model is that as density tends to zero, speed tends to infinity. This occurs because n is very small compare to n_s thus value of logarithmic function becomes very large making the flow velocity very large. This shows the inability of the model to predict the speeds at lower densities. To overcome this problem we use Underwood's model. Speed becomes zero only when density reaches infinity which is the drawback of this model. As n becomes large in quantity, the exponent term becomes very small, near to zero. Thus the predicted.

$$v = v_f \times log(n_s/n) \tag{2}$$

$$v = v_f \times e(-n/n_s) \tag{3}$$

We would use the available traffic cameras at the junction for finding the traffic density. If the junction is a cross road, there will be four cameras facing the roads such that incoming traffic could be seen through cameras. These cameras are used to detect traffic density using computer vision techniques like YOLO [15]. YOLO algorithm would help us to know how many vehicles are present i.e traffic density. The computation and image processing is done using python's openCV library using a micro-controller Raspberry-pi 3. YOLO is a very fast and robust object detection algorithm. It is also able to also differentiate between various kind of vehicles like Ambulance, Truck, bicycle, car etc. YOLO can detect the vehicles in image, so, for example, if an image has 3 cars, YOLO will detect 3 cars, so we have the count of vehicles. Traffic density is the number of vehicles per unit area. Once we have the traffic density, we focus on other parameters which are not dynamic but is useful to predict the time required for vehicles to pass the crossing. One such factor is number of lanes. If there are more number of lanes on road, less time is required to clear the traffic. It can be understood as area of opening of pipe, greater is the area, greater is the volume of fluid flow through it.

The number of lanes is a static feature as for a road the number of lanes don't not change dynamically. One other feature is length of crossing, greater the length of crossing, more time the vehicles take to cross it. This is also a static feature as the structure of the crossing does not change with time. These static features could be pre-programmed for a given junction or road. On these factors we can predict the time required by the vehicles to cross the junction. This would be synchronized for the whole junction, for example let's say junction is a crossroad with 3 lanes each. Let's name the roads as A, B, C and D. Once the traffic of A is cleared the same algorithm is applied to B automatically and a sequence is maintained throughout. At regular intervals the algorithm checks if there is a special vehicle present at any road which needs to be prioritized, if a special vehicle is found first traffic is cleared on that road then again the cycle is maintained. An upper threshold is also fixed for time, as when there is heavy traffic on a road, the time predicted would be large, and this would create starvation for other roads leading to congestion in traffic. So if the time predicted it above the upper limit then time would be set to upper limit. This would prevent starvation to other roads.

The key point of this method is that the behavior of the traffic is considered in the modeling of traffic flow model and prediction of the time for vehicles to pass. The method is easy to implement with very simple features and features are easy to identify. The model requires very less computation, we just need to detect the cars and find the traffic density, this is where most of the computation is required. Other factors are static and can be decided prior to deployment. Model is also synchronized at the crossroad, this means that whenever traffic on one road is cleared, automatically next road is chosen and traffic is cleared of the road and so on. This process goes in infinite loop. The architecture used for the model is minimal and thus the model is cost effective.

The whole process can be divided into steps as shown below:

- We start with any one road at the junction to start with the algorithm.
- Collection and Pre-programming of data: Data is collected of road like number of lanes, the length of crossing and free velocity is determined. These parameters does not change with time.
- The algorithm starts just before the time to turn the signal green so that we get the traffic density when we are about to clear the congestion. An image is capture at that instance.
- Once image is captured, we use YOLO algorithm to determine the traffic density at a junction, the processing is done using a Raspberry-pi.
- Once we have the traffic density, we would use it along with other to calculate the necessary time T_g to clear up the traffic. T_g is the time for which signal would turn green for a particular road so that vehicles could pass the junction. For the calculation of T_g, we need to calculate the flow velocity. This is calculated using the traffic flow models using traffic density. Traffic density depends on number of vehicles and number of lanes on a road. Once we have calculated the flow velocity, we have to calculate the time take by all the vehicles to cross the velocity the crossroad junction. Now we use the the length of crossroad and velocity to calculate the time required for vehicles to pass the the crossroad. Since the vehicles are queue, thus the length of queue is also considered in length.
- For the time calculated, we check if the time exceeds the upper limit, if it does we set the time to upper limit and open the signal according to it. If not, we open the signal for the calculated time.
- Once the timer comes to end, I.e. the time for which the vehicles are allowed to pass, automatically same algorithm works for the next road at the crossroad.
- This process eventually becomes a cycle which continues throughout in a loop.

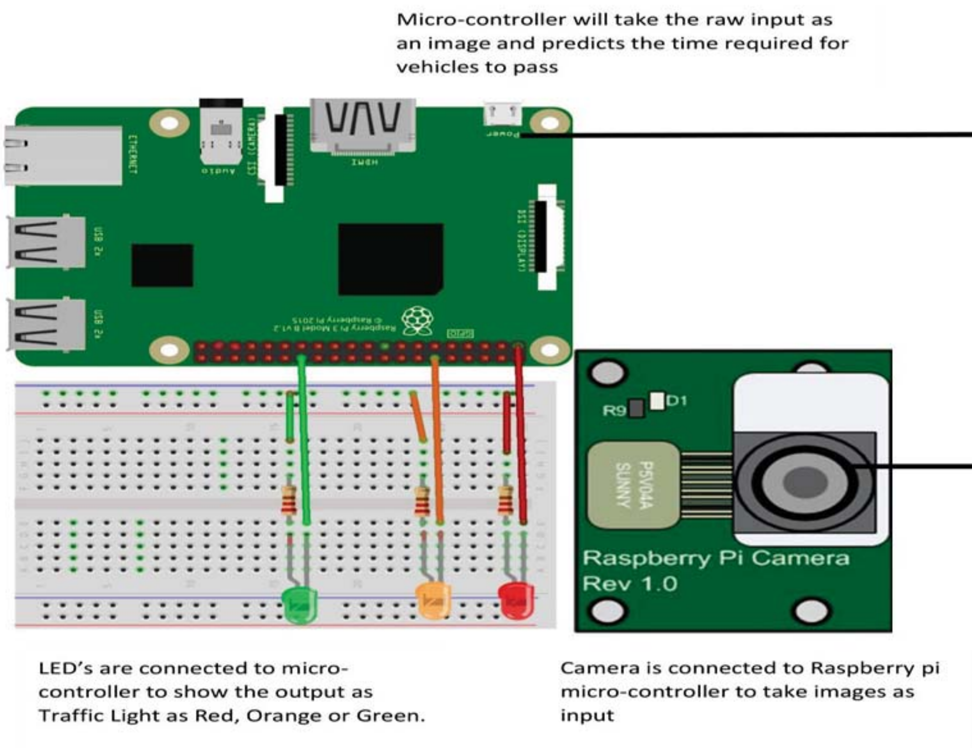

Figure 1. Prototype for proposed model

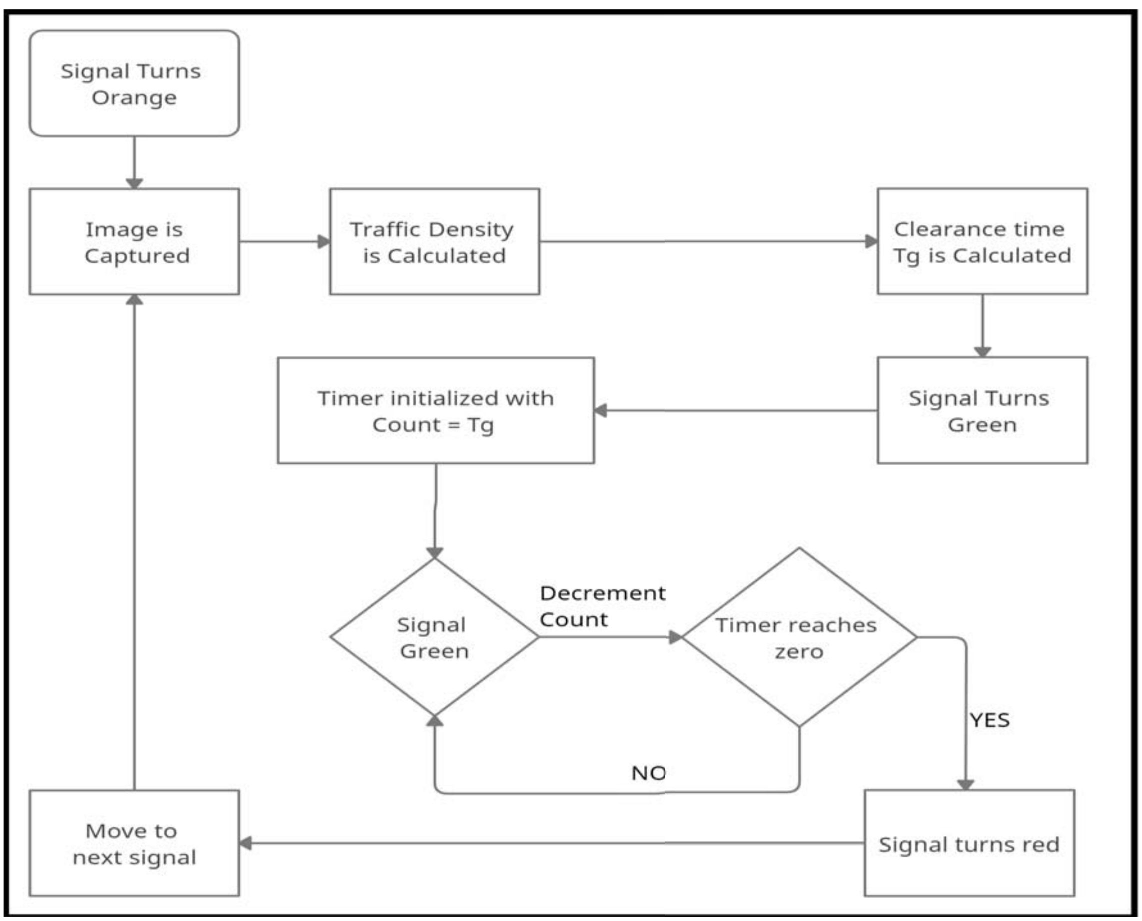

Figure 2.Traffic control system architecture

5 Experimental Analysis

The main task of the proposed model is to predict the time required for the vehicles to pass given various parameters like number of lanes, traffic density and length of roads. For the sake of simplicity we have all the vehicles to be similar. Given various formulae above, relations were made between predicted time and parameters. Below are the figures 3-11 indicating the relations between time with different parameters. All the values are standardized.

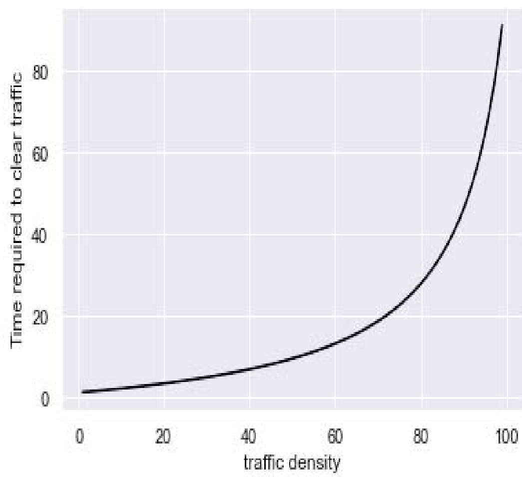

Figure 3. Relation between traffic density and time using Greensheild's model with constant lanes

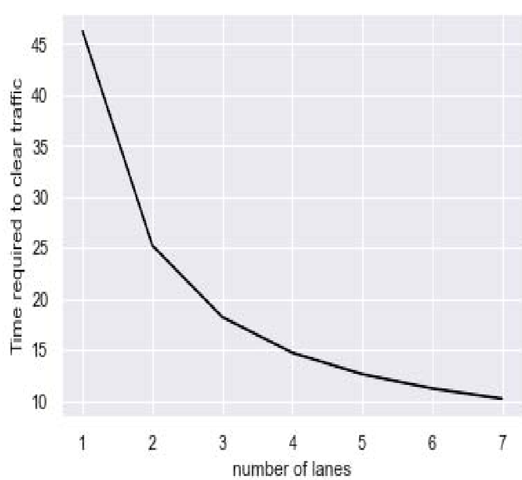

Figure 4. Relation between number of lanes and time using Greensheild's model with constant traffic density

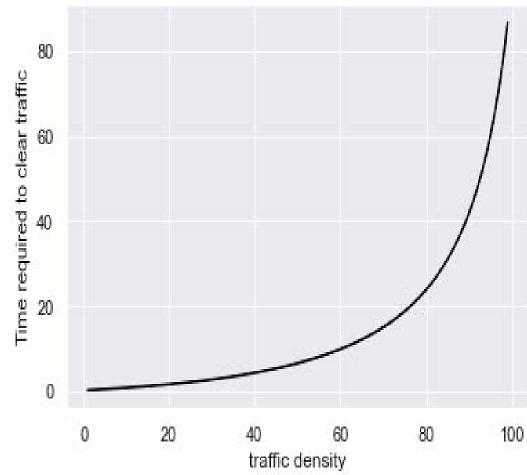

Figure 5. Relation between traffic density and time using Greenberg's model with constant lanes

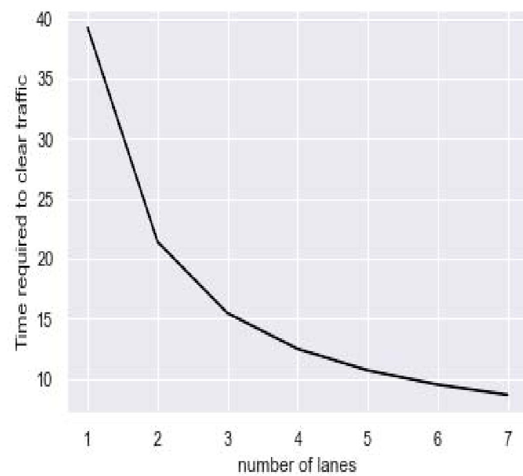

Figure 6. Relation between number of lanes and time using Greenberg's model with constant traffic density

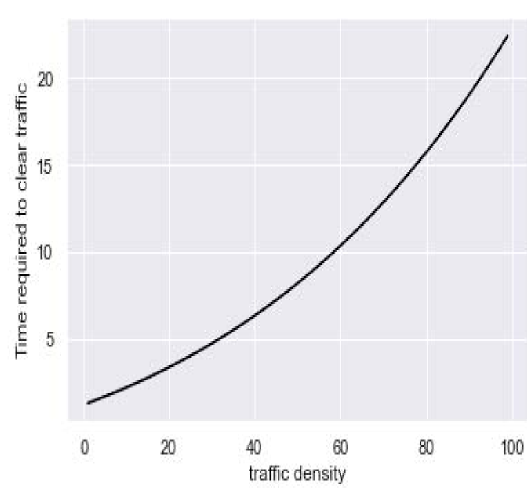

Figure 7. Relation between traffic density and time using Underwood's model with constant lanes

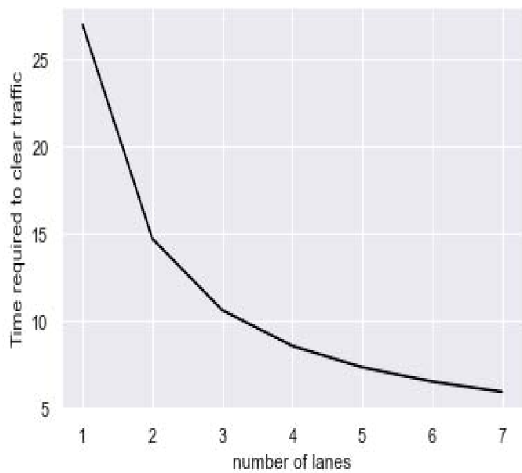

Figure 8. Relation between number of lanes and time using Underwood's model with constant traffic density

Once common trend in all three traffic flow models is that we can see here is that, as number of lanes increases, the T_g calculated decreases. This is because the overall traffic density decreases as traffic gets distributed in the lanes. Also the queue length of the is decreased. Here we have an assumption that traffic gets evenly distributed in all the lanes. Also the T_g and traffic density has a increasing trend. Here we made number of lanes constant as we wanted to study just the relation between traffic density and time. The increasing relational could be interpreted by the formulas of traffic flow models mentioned above.

6 Conclusion and Discussion

As we can see that the used methods are independent from traffic density, thus wasting the lot of resources, like time and energy, earlier proposed methods used are not fully dynamic in nature which makes it inefficient. The proposed methods in this paper is focused on fully dynamic traffic managements system making it most efficient. This method is practical and can be implemented with lesser equipment. This makes the proposed method easy to implement and replace the current system. We could also store the processed data which could be used for analysis which can be used to predict traffic at different areas of cities and making necessary infrastructure for future upgrade the transportation and building of smart cities.

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