Intelligent Traffic Light Scheduling using Linear Regression

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Abstract A standard traffic light scheduler applies fixed time intervals for the green lights. This might sometimes result in traffic congestion and blocking of roads. To overcome this problem this paper obtains a solution for scheduling the traffic light using a multiple linear regression model. This paper presents a model of how to achieve a traffic light schedule which is more efficient in terms of the number of vehicles stopping at the red light in each direction, and more effective to reduce traffic congestion as compared to traditional scheduling methods. Green time is the amount of time a directional light will have a green signal. This work presents an algorithm and a model to analyze the traffic density at different times and predict the green time for each directional traffic light such that the probability of traffic congestion is reduced and orderly flow of vehicles on the road is achieved. After applying this model, the number of vehicles stopping at the red light at a given time decrease by around 11%.

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1 Introduction

With the increase in population and number of vehicles per capita in cities around the world, road traffic control has continued to be a big problem for city planners. It is very difficult for the cities to expand their road infrastructure. Even if it is possible to increase the number of roads, it is almost impossible to apply it in the central areas of a city. Thus, they have to rely on various traffic control mechanisms. Traditional traffic light consists of red and green light, where green light means it is safe to cross the road and flashing red light means don't cross the road. Traditionally a standard traffic light applies fixed green signal time to each and every direction irrespective of the traffic density in a particular lane. This paper makes the use of traffic density details from different directions in order to calculate the optimum green ratio.

Instead of using a fixed green signal time for each direction this paper presents an algorithm which dynamically calculates the green signal time for each direction by using multiple linear regression model to predict optimal green ratios. It is important to have a proper and consistent data in order to optimize the Traffic Scheduling. For this to happen it is important to capture the number of vehicles on the particular lane and for this purpose, one can make the use of a highly efficient camera such as AIS-IV Camera. An inductive loop can also be used in order to detect the presence of vehicles. The inductive loop makes use of a moving magnet or an alternating-current. The green ratio of a direction is defined as the ratio of green signal time of that direction to the total cycle time of that signals. This model has two applications, one when adequate resources are available to count the current number of vehicles on an intersection where the vehicle density and time can be given as an input to the model, and output will be the green ratio. Another application is when these resources are not available, the values of directional traffic can be taken from previous data and only current time will be required to obtain the green ratios.

2 Related Works

The standard traffic light scheduling method is efficient for handling daily traffic. But this model fails in places with unusual traffic patterns. This paper deals with change in traffic pattern every 15 minutes. A sudden change in traffic can be easily handled with this model.

There are few works done in this field. In [1], Wireless sensor networks are used to monitor real-time traffic. Their work only determines the number of vehicles but does not consider time as a factor. Though collecting real-time data for scheduling traffic light might be accurate but predicting the traffic density at different times will be more efficient. The paper [2] focuses on vehicular ad-hoc technology, which requires that every vehicle in the influential radius of the traffic light must have a GPS (Global Positioning System) and should be able to communicate with the system. The position, speed, and vehicle density are calculated from each vehicle in the radius. This requires an existing infrastructure in all the vehicles. Whereas the Intelligent Traffic Light Scheduling using Linear Regression requires cameras and image recognition to calculate the number of vehicles. The authors in [3] have calculated the average arrival rate of vehicles using an algorithm. The arrival rate is based on the various factors including the current number of vehicles in a queue. This model also does not consider the time as a parameter. The throughput can be increased if the expected number of vehicles at a given time is predicted beforehand.

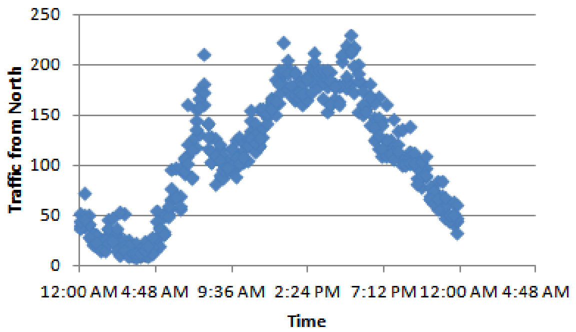
3 Proposed Work

In this paper, the traffic is analyzed and a traffic light schedule is developed for a four-way intersection. First, a green ratio is calculated for each direction for each cycle of the traffic signal with the mentioned algorithm. An optimum green ratio is the distribution of cycle time of the traffic signal in such a way that the number of vehicles stopping at the red light is minimum. A cycle time of a traffic light is the total time for the traffic light to complete its cycle of green lights for each direction. The obtained green ratio along with traffic densities and time are fit in a multiple linear regression model. Then, the green ratios are predicted based on the input test data.

3.1 Analysis of Traffic Patterns

The current traffic patterns of an intersection are analyzed. The average number of vehicles crossing the intersection in a day is plotted with respect to time.

Fig.1. Time vs North Traffic



From figure 1 it is clear that the maximum traffic flow is around 8 am in the morning and 6 pm in the evening. A similar pattern occurs in all the other directions. The probability of traffic congestion is high during these peak hours. Efficient traffic scheduling is required the most around these times.

3.2 Architecture

The green ratios calculated from the multiple linear regression model are passed to the dynamic traffic scheduler. This scheduler calculates the actual green signal timing for each direction and passes it further to the traffic signal. The regression model is trained from the ratios calculated by the mentioned algorithm. To predict the green ratio values, the model must be given the time and number of vehicles in each direction as input. The number of vehicles at a given time can be calculated using the methods mentioned above i.e. cameras and inductive loops. With the multiple linear regression model, green ratios at a given time can be predicted. The green ratio is calculated for each direction for each cycle of the traffic signal. Direction with the maximum traffic density will have the maximum green ratio as compared to other directions. In this way, we can predict the green ratios of all the directions and hence we can effectively switch between the red light and green light of different directions.

3.3 Algorithm to calculate Green Ratio

A simulation program was developed in Python to practically simulate and apply the changes of signal timings and its effect on the traffic on each road. Assume the frequencies at which the vehicles arrive at the intersection from all four directions be nfreq, efreq, wfreq and sfreq respectively. The above-mentioned simulator will increment the respective variables based on these frequencies. Assume the total cycle time as ’T’, number of lanes as ’N’, the time required for a vehicle to cross the stop line as ’t’. Here, it is assumed that the number of vehicles is equally distributed on the number of lanes for a given direction. Let nratio, eratio, sratio and wratio be the green ratios of north, east, west, and south direction traffic lights respectively. Initially, all four values are set to 0.25, indicating that all the directions will have an equal share of green light where 0.25 represents the ratio of green time of a particular direction to the total cycle time. This algorithm will change this ratio to the optimal green ratio.

There are four lanes from North, South, East and West direction which meet at an intersection. Initially, all the four directions are assumed to have equal traffic density. Hence equal green ratios are set for all the directions for the first cycle. Only for this first cycle, the green ratio is 0.25. After the first cycle algorithm will work with these initial green ratios in order to calculate the optimal green ratios for all the directions based on the traffic density. This algorithm works on the basis of greedy paradigms hence it is necessary to give equal green ratios to all the four lanes (1/4 lanes = 0.25). The given scenario is simulated for one traffic light cycle. After which the direction with the most number of vehicles is obtained. The green ratio of this direction is raised slightly by a value of ’d’. To maintain the sum of ratios as 1, a value of d/3 has to be subtracted from all other ratios, thus slightly decreasing the green time for that direction.
For example, after the first cycle if west direction has the most traffic, its green ratio will be wratio = 0.25+d, nratio = 0.25-(d/3), eratio = 0.25-(d/3) and sratio = 0.25-(d/3).

But if the traffic from one direction is extremely high, the ratio for that direction may reach 1, disabling the green light for all other directions. To overcome this problem, some constraints are added while changing the ratio. For the program we used, the values of variables are as follows T = 120 seconds [5], N = 3, the roads have three lanes, d = 0.03, t = 2.5

seconds [6], where ’t’ is the time required for a vehicle to the cross the stop line. The more iterations the above program runs on, the more accurate are the ratios. Once the green ratios are obtained for each direction, they can be applied in the Multiple Linear Regression Model.

From the dataset, the traffic density of the particular direction can be easily obtained. The algorithm which is based on multiple linear regression model is used to calculate the optimal green ratio of the particular direction based on its traffic density.

The green ratio of a particular direction is solely based upon the traffic density. Suppose if the north direction has maximum traffic density then the green ratio of the north direction will be maximum. The algorithm sets a maximum and minimum limiting values for the green ratios such that each and every direction could get a fair and optimal green ratio time. Hence in this way, the optimal solution for the traffic congestion management is obtained.

3.4 Model – Linear Regression

Linear is a statistical method that finds the relationship between at least two attributes. From all these attributes, one is dependent and all the others are independent. With the help of this statistical model, we can predict the dependent variable using the other independent variables.
The representation of a multiple linear regression is a linear equation that combines a specific set of input values (x) the solution to which is the predicted output for that set of input values (y). For a simple regression (a single x and a single y), the equation would be: -

$$y = B0 + B1*x$$

This equation represents the equation of a line. The multiple linear equation is given by: -

$$y=B0 + B1*x1 + B2*x2 + ... Bn*xn$$

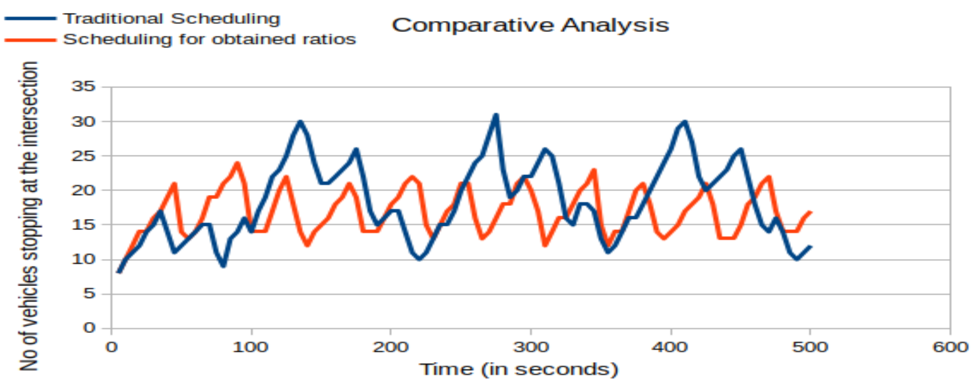
Here, B0, B1, B2...Bn are regression coefficients.
For multiple linear regression, the equation represents a plane or a hyperplane. For this paper, a multiple regression model is applied. The green ratios obtained from the algorithm are fitted to a multiple linear regression model along with the time and traffic from each direction at that time. The green ratio is the target attribute. After plotting the regression model from

the training data, one can obtain the green ratios by entering the time and number of vehicles.

3.5 Comparative Analysis

Comparative analysis is done to compare the traditional traffic light scheduling with this model. For the comparison between the two, the traffic from all the direction is monitored at regular intervals of 5 seconds. This comparison is done for the data values of 7:30 AM.

Fig. 2. Comparison for north direction traffic between traditional and new model



We obtained the traffic data of 45th St. & Main Ave., Fargo, North Dakota, US. We used the website [4] to obtain the datasets which contained monthly average values of traffic from each direction of the intersection at a 15-min. interval.

There are no particular ratios in traditional scheduling. The ratios vary from intersection to intersection based on the type of the road and general traffic flow. But, all these ratios are constant with respect to time. For the purpose of comparative analysis, the green ratios for each direction for traditional scheduling were calculated based on the traffic density ratio in each direction. The average values for both the graphs are: -

- For Traditional Ratio Distribution = 18.37 vehicles.
- For Predicted Ratio = 16.81 vehicles.

This is around 11% decrease in the number of vehicles stopping at the red light. It can be concluded that this model is more efficient than the traditional model with equal distribution.

4 Conclusion

This paper has highlighted the need for a new traffic scheduling method. When the obtained linear regression model was applied to a test data, the accuracy of prediction of green ratio was in the range of 55% to 60%. It was found that this model is better than the traditional scheduling model on the basis of avoiding traffic congestion. This model decreases the number of vehicles stopping at the red light at a given time by around 11%.

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