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Smart Traffic Management Using Data Analysis

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Abstract: Due to the modern availability of live traffic update, optimizing waiting time is now possible. The traffic flow has specific pattern that is followed, as to which direction the traffic is at its peak during a particular time. Consider during mornings and evenings the majority of the traffic movement directions is always opposite, even during weekends and on holidays the flow of traffic tends to change. Taking in account these above mentioned factors, keeping a static waiting duration for every traffic light on every side of the intersection, leads to the problem of bottleneck where one particular direction where traffic tends to be heavier given a green signal the same amount of time another direction which has considerably lesser or no traffic at all. Therefore, implementing a system which aims to reduce chances of such scenarios, by automatically computing the optimal time a signal phase should be permitted as well as keeps adjusting constantly until an optimal equilibrium is reached where the direction with more traffic is allotted a green signal for longer duration of time as compared to the direction with lesser traffic. The goal of this system is to dynamically adjust time duration for each traffic lane. The system begins with logging down the traffic at every side of the intersection every minute. These information can be pooled by using numerous applications, right from Google live traffic updates to installing sensors, and computing the allow time for signals, thereby improving the efficiency of traffic signals and optimizing the time delay
Keywords: Traffic management, Traffic signals, time optimization, data analysis, dynamic time adjustment, traffic pattern.

I. INTRODUCTION

A sophisticated standard of living lead to a tremendous increase in the number of automobiles produced at more affordable. As per the article in New York Time states a study by Experian Automotive, which specializes in collecting and analysing automotive data, Americans own an average of 2.28 vehicles per household, and more than 35 percent of households own three or more cars[1]. As the population grew in hand with the standard of living, the traffic caused due to the increased number of vehicles also skyrocketed. To keep in check the smooth flowing of traffic between multiple roads, traffic signals were implemented. The main idea behind traffic signal was to allow traffic from each direction at an intersection for a certain duration of time while holding the traffic from other directions.

The deployment of traffic lights did provide a administered flow of traffic, however, the system fails to be efficient for the commuters. According to a study, On an average, every America's drivers spend 6.9 billion hours stuck in traffic in 2014, as per a study released by the Texas A&M Transportation Institute(TTI) and INRIX. That's 42 hours a year per rush-hour commuter on an average[2]. The main reason behind the low efficiency of traffic signals, is they fail to adjust according to the increase in the traffic. Every traffic signal provides a green light for a predefined amount of time, and then turns red, irrespective of the traffic present at that end. Also, the heavy traffic direction changes during peak working hours.

There are various applications that are used to gauge the live traffic status a few of them are Google maps, live traffic info, traffic watch, traffic reports etc. Google maps and other similar applications have a similar concept in which they operate i.e Every time a user uses Google Maps and allow it to access your location, the app will also send location data back to its servers, if when location is on a roadway, it is able to analyze in real-time whether your actually moving or stuck in traffic. Google is able to see where there is heavy traffic during a particular time, by pooling information from millions of users around that data and accordingly live traffic analysis is available to the user.

II. OVERVIEW OF SMART TRAFFIC MANAGEMENT SYSTEM

A. Overview of proposed system

To tackle the issue concerned with increasing traffic and improving the efficiency of traffic signals, we developed a system which dynamically adjusts the duration for which to allow traffic to move from a particular direction. The system takes note of live traffic updates and logs the traffic, the time for which the signal is to be turned green, every time just before the signal at that direction turns green. By logging this information the system learns and determines the optimal time duration for which to allow a signal to be green or red at a particular time.

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For recording traffic at a direction on an intersection, multiple tools can be used. Live traffic updates provided by Google Maps or installing sensors or cameras and performing image processing can also be considered. The traffic recorded is in the unit of meters from traffic signal. Every time just before a traffic signal turns green, the total length till the last vehicle waiting for the signal is recorded in meters. This is the distance that is logged and used by the system to adjust the waiting duration accordingly.

According to the current working system of pre-timed traffic signals they are allocated a length 100 seconds for a red phase and about 60 seconds for the green phase. According to a study figures mentioned in the Table 1 are the vehicles per day that cross intersections [6].

TABLE I: FONT SIZES FOR PAPERS

Lanes	Vehicles per day
4 lane freeway	72,000
6 lane freeway	108,000
4 lane (w/ left turn lanes)	31,000
6 lane (w/ left turn lanes)	44,000

Theoretically maximum saturation flow rate per lane could be 1900 vehicles per hour[5], based on this information we can conclude that every 0.53 second a vehicle passes through when a signal goes green. Considering, the average length of a vehicle is 4.5 meters, and also taking into account additional time required to start engines, as well as waiting for the vehicle in front to provide safe distance to move once the signal turns green, we can safely assume to move 1 meter of accumulated traffic once the signal turns green can take up to 0.6 seconds.

T=Time to pass a 1 meter long traffic through the signal.

$$T = 0.6 \text{ seconds} \tag{1}$$

B. Difference over Conventional System

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Traffic signals were designed to: Ensure safe and orderly flow of traffic. Protect pedestrians and vehicles at busy intersections, to control this signals there are various methods proposed the Fixed time (FT) in this the traffic signals are allocated a constant pre-computed time in which they turn green and back to red, the problem with this approach is the FT controls fails to handle complex, time varying traffic conditions[3][4]. The vehicle actuated control (VAC) replaces the traditional method, in this there are vehicle actuators that register the traffic demand and accordingly extend the length of the green signal, however it is inefficient because it only determines the traffic on the lane that has right to way, without taking into account the red gone lanes[5].

Fig 1: A typical intersection

The system we proposed pools data from a live traffic source such as Google Maps to get live traffic information. The benefits of this systems over the vehicle actuated control (VAC) system is that it does not need any vehicle actuators to gauge the traffic on the lane, since it keeps track of live traffic arriving at the intersection and sets time accordingly without any complex mathematical calculations. This leads to extending the green stage inefficiently, particularly when there are long queues waiting at red signals. Moreover, it considers all types of automobiles that share in and compete together for the same road space, a simple algorithm runs to calculate the green signal time and red signal time, utilizing all the available information from live traffic source.

III. WORKING OF THE SYSTEM

In the proposed system, the terminology traffic allowed from a particular direction/signal means the traffic coming from a direction is given green signal to move at all the sides of the intersection, while traffic arising from the remaining directions at an intersection has a stop or red signal.

The system comprises of certain predefined variables to which administer the system and regulate the issue regarding traffic at particular direction being allowed for too long or waiting too long, also termed as starvation.

T_{min} – Minimum time duration signal should be green at any direction of an intersection.

T_{max} – Maximum time duration signal should be green at any direction of an intersection.

T_n – Allow time, the time duration for which traffic is allowed at signal n.

While implementing the system, Tmin and Tmax have to be specified, and the system will make sure the allow time always falls in the range of Tmin to Tmax.

In an intersection, consisting of 4 directions with 4 traffic lights will have a corresponding allow time of T1, T2, T3, T4. Thus each of the 4 signals will be turned green for their corresponding allow time at a particular time frame. Once the allow time for signal T1 is completed, the signal is turned red, and the next signal with allow time T2 turns green. This cycle continues indefinitely across all the signals at the intersection.

In the initial run when no data mining is performed, the allow time Tn is calculated as follows:

$$Tn = \frac{Tmax + Tmin}{2} \qquad (2)$$

Tmax and Tmin being the same for all the signals at an intersection, initially the allow time is same for all directions.

Every time, just before traffic from a signal is allowed, the length of the accumulated traffic along with the time is recorded and stored in a database. The length of the accumulated traffic at direction n is the distance from the traffic light to the last vehicle waiting and is denoted by Ln.

Ln – Length of accumulated traffic at signal n in meters.

A. Computing Allow Time

For the most optimal results, each new T_n will be calculated for signal n and valid for 15 minutes. T_n will be based on the past traffic data to predict the traffic intensity for the text 15 minute time frame. For calculating T_n past traffic data from the same time frame from the same day of the week is used. Accordingly T_n for the next time frame is calculated for every signal. The reason behind this approach is the traffic tends to be same at the same time duration of a day, and also the traffic during the weekdays, weekends tends to be of rather different intensity.

To prevent the consequences due to sudden unprecedented traffic surge, along with the previously logged traffic length, the current traffic status is also considered.

B. Estimation of next traffic length for computing allow time

For the most optimal results,

For calculation of allow time Tn at signal n, for next time frame, the next length of traffic Ln(new) has to be estimated. Ln(new) is calculated using average of last half of the total logged entries m of Ln at the same time frame at the same day of the week at signal n. The calculation for Ln(new) is as follows

$$L_{n(new)} = \frac{\sum_{k=\frac{m}{2}}^{m} L_n}{\frac{m}{2}} \qquad (3)$$

$L_{n(new)}$ – The estimated length of traffic at signal n for the next time frame.

When using the above equation, once $L_{n(new)}$ is calculated from the previous data, it is also necessary to consider the current traffic at signal n. As the traffic in the next time frame will be in proportion with the current traffic, $L_{n(new)}$ is compared with Ln which is the length of currently accumulated traffic at signal n. This also helps to overcome the issue concerning sudden increase in traffic. If the

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difference between $L_{n(new)}$and L_n is greater than 10 meters, the Ln(new) is adjusted by taking the average of $L_{n(new)}$ and twiceL_n as shown in the equation (4)

$$L_{n(new)} = \frac{L_{n(new)} + 2L_n}{3} \quad (4)$$

Once $L_{n(new)}$ has been calculated, the corresponding T_n for the particular time frame is calculated. The calculation is based on the finding that to move 1 meters of traffic 0.6 seconds are required as mentioned in *(1)*. For better efficiency, half of the $T_{min}$is added to the calculated value of T_n. This is to alleviate the impact of incoming traffic during the signal is turned green. Calculation of T_n is explained below:

$$T_n = 0.6\left(L_{n(new)}\right) + \frac{T_{min}}{2} \quad (5)$$

The value of T_n calculated is the time for which signal n will stay green during the next time frame. Once the T_n has been calculated, it has to be determined if it meets the T_{min} and T_{max} that have been defined for the intersection. If the calculated T_n is less than $T_{min}$the T_n is allotted the value of T_{min}. If calculated T_n is greater than T_{max}, the T_n is given the value of T_{max}.

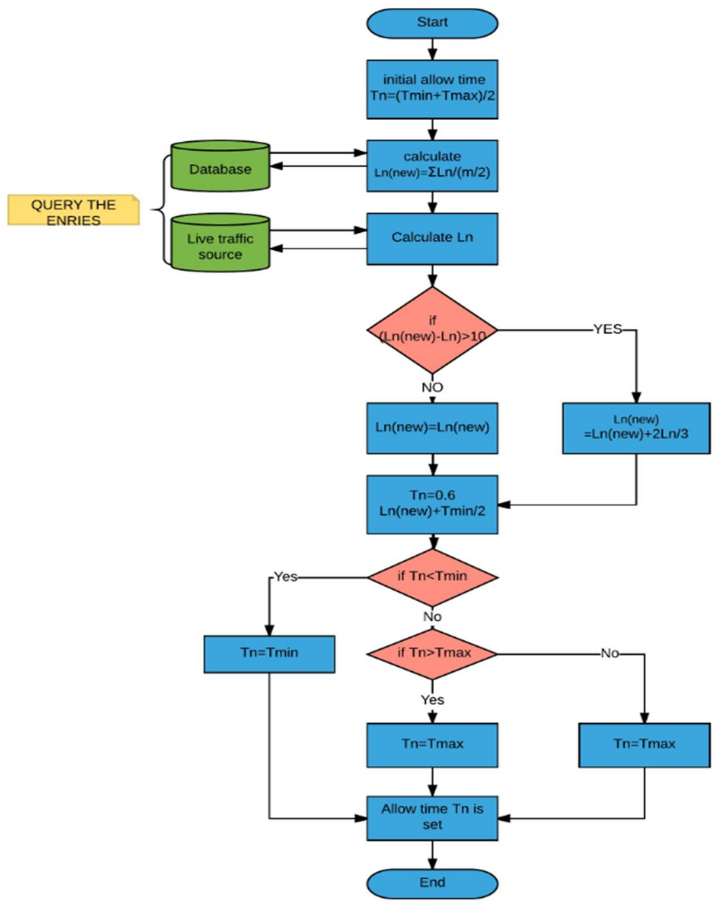

Fig 2: System Workflow

Once the value of T_n is calculated, it is rounded off to the nearest whole number and assigned to the corresponding signal n for the upcoming time frame. Similarly, for all the signals at the intersection their corresponding value of T_n is calculated and assigned. Each signal execute a green signal for time interval of T_n, once the duration of T_n is completed, signal n turns red and the next signal executes its green signal for its corresponding time interval. This process goes on in a cyclic manner for the time frame, until just before the end of the time frame when the new values allow time have to be calculated for all the signals and the above mentioned process repeats itself indefinitely

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IV. DEMONSTRATION OF WORKING

Consider a scenario where at signal S1, on a Tuesday, next allow time from time frame 9:00 to 9:15 has to be calculated. At this intersection, the predefined value of T_{min} is 20 seconds and T_{max} is 100 seconds. Currently the traffic at signal S1 just before the signal turned green, the length of traffic L_n obtained from live traffic source was 60 meters.

Considering the above mentioned parameters, let's consider two cases in finding the allow time T_n at signal S1 for the time frame 9:00 to 9:15.

A. Case-1: Difference between $L_{n(new)}$ and L_n is 8

The value of $L_{n(new)}$ is computed, the formula mentioned in equation (3) is used for this calculation. The data for the time frame 9:00 to 9:15 on last half of the data for same time frame on Tuesdays is considered. The value obtained from equation (3) is supposes 52 meters. The value of Ln(new) and Ln, the difference between them is no more than 10 meter, so the value of Ln(new) that is meters is preserved to calculate the allow time. From $L_{n(new)}$, the allow time T_n has to be calculated as shown in equation *(5)*.

$$T_n = 0.6(52) + \frac{20}{2} \qquad (6)$$

≈41 seconds

Now , this value of Tn is compared with the Tmin and Tmax value since calculated value of Tn fits the range of Tmax and Tmin the allow time for signal S1 is set

B. Case -2: Difference between $L_{n(new)}$ and L_n is greater than 10

Here, we assume the Calculated value of $L_{n(new)}$ is 40 meters using (3) and that of Ln as mentioned above is 60 meters, we compare the value of Ln(new) with Ln and since the difference between both the lengths is greater than 10 meters, the new value of Ln(new) is computed using equation (4)

$$L_{n(new)} = \frac{40 + 2(60)}{3} \qquad (7)$$

=53.33 meters

Hence the value for T_n is computed as mentioned in equation (x)

$$T_n = 0.6(53.33) + \frac{20}{2} \qquad (8)$$

≈42 seconds

This value of T_n is then compared with Tmin and Tmax, it satisfies the condition (Tmin<Tn>Tmax), therefore the allow time is set to 42 seconds for the given criteria.

V. CONCLUSIONS

In this paper, we have proposed a solution to overcome the major concern relating with traffic signals and traffic jam. The way the system is designed, the system initially has same value of allow time across all the signals at an intersection. Witheveryiteration, the system learns and optimizes itself improving its efficiency. The system later reaches an equilibrium where allow times predicted for the time frames are exactly proportional to the traffic. Also the chance of a sudden increase in traffic is also covered by comparing the calculated $L_{n(new)}$ with the current value of L_n

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Sneha Leleat Gonsalves compeleted B.E. in Computer Engineering from St. Francis Institute of Technology in 2017.She has been keen towards areas that focused on ERP, Data-Mining and Information Management, and has constantly been putting efforts to get better at those areas during all her course because she believes " You get what you work for, not what you wish for".

Mark Malcolm Furtado received the B.E. in Computer Engineering from St. Francis Institute of Technology in 2016. During his course of engineering he mainly emphasized on Data Mining, Information Management, ERP and Web Technologies. Alongside he also shares enthusiasm for programming and strives to find simpler solutions to complex problems using technology. He believes "The harder I work, the luckier I seem to be".