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# Development of an Intelligent Traffic Light System in Decongesting Traffic Density Using a Non-Pretimed Method

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**Abstract- Traffic light system is a means to automatically control vehicle congestion without human intervention. An obvious challenge in the operations of traffic control is such that irrespective of high congestion on a given side compared to other sides, the same amount of time is given to each side of the junction, which should not be the real sense of decongesting traffic. Therefore, this paper is presenting a time-control system to allot more time to highly congested side than to a less congested side at a given point in time. The system employed linear algebra algorithm to formulate the mathematical model for the time-control. The model was implemented in MATLAB environment with red, green and amber colours to indicate stop, go and ready respectively. The time-control system was able to allot more time to highly congested vehicles to pass. The developed system is more efficient in the way a traffic light system decongests vehicles against the tradition approach to decongestion.**

**Keywords:** Congestion, Decongestion, Intelligent Traffic System (ITL), Traffic, Traffic density, Traffic light***s domain.***

## 1. Introduction

An electric traffic light was invented in the year 1912 by a Utah police officer called Lester Wire. It has indication light of only green and red. In 1914, the first traffic signal designed by James Hoge was installed in Cleveland, Ohio which had a buzzer apart from the red and green colour indication lights. The buzzer was used to provide warning of the colour changes. It was both used by police and fire stations to manage signals in emergency. The first four-way three-colour traffic light was invented in the year 1920 by police officer William Potts [1].

The primary purpose of traffic signals is to separate conflicting traffic by the division of time, within the available road space, in a safe, efficient and equitable manner. Conflict at an intersection is manifested as an increase in delay and/or accident rate. [2]. Traffic light control is a system that automates the activities of a traffic police or warden. A traffic warden directs the affairs of traffic so that there can be sanity on the road. The mechanics designed to mimic what a traffic warden would do are the use of signal lights to indicate several actions that a warden would initiate to direct or control traffic. Actions initiated by traffic warden are move, stop and get ready to move which are emulated with the use of green, red and amber lights indicators respectively. Major advantage provided by the traffic light control system are fatigue does not come into play, it can be present at any time of the day be it in the rain or under hot weather or even in the midnight. All these conditions are what traffic warden may not be able to do. Conventional traffic system consists of two parts. First part is traffic light and the second part is controller unit [3]. The controller unit represents the brain of the traffic system. It consists of a computer that controls the selection and timing of traffic movements in accordance to the varying demands of traffic signal as registered to the controller unit by sensors [4].

Traffic light system directs traffic by allotting time to each lane of a junction in an equal time round robin manner. Unlike human being (Traffic warden) which uses his sixth sense to determine when to give more time to the lane that is more densely traffic congested than the lane that is less densely congested.

Considering a case of Nigeria; People in the traffic gets annoyed at the fact that the traffic light cannot intelligently act like a traffic warden would have acted especially when they are on the side of the road that are heavily packed with vehicles. The same one or two minutes duration for passing traffic on the side of the road with few cars (say 10 cars) is the same amount of time that is allowed for the lanes having large amount of cars (say 1000 cars). This condition is not desirable for road users and therefore wants a situation where a traffic light system can intelligently decide to allocate time based on the traffic presence.

Back in the days, the change in colour of traffic lights was based on fixed timings. That is, regardless of whether there is vehicle on a lane or not green light will still be on for the same amount of time for each lane in a round-robin version. Existing methods consists of signals that act in response to the presence of a vehicle. This is achieved through a sensor loop embedded in the pavement which detects weak magnetic fields such as metallic parts of cars. The sensors are wired to a controller which is a computer that reads the signals (presence of a vehicle) that is detected by the sensors. If there are no vehicles on a lane, the right of way will (no green light) not be given to it [1]. According to [5], traffic light indicator are “GO” (green), “READY” (amber), and “STOP” (red). If the North-South lanes are the Arrival, then the West-East lanes are the Queue and vice versa.

Intelligent Traffic System known as ITS have been implemented in developed countries like America, United Kingdom and Japan and researches are still on-going [6]. Two major classifications of ITS are real time system and data analysis system. Real time system is further classified into path optimisation and traffic density. Real time systems involve taking input from current situation through video surveillance or WSNs (Wireless Sensor Networks) and deals with the situation [6]. In this modern era, every system is automated in order to face new challenges. Due to this demand every field prefers automated control systems. Especially in the field of electronics automated systems are giving good performance. And this is realized by making use of Zigbee technology for communication. Zigbee is new wireless technology guided by IEEE 802.15.4 Personal Area Network standard. It is primarily designed for the wide ranging controlling applications and to replace the existing non-standard technologies [7]. The idea behind intelligent traffic systems is that drivers will not spend unnecessary time waiting for the traffic lights to change [4].

## 2. Methodology

Using a vehicle detecting sensor laid on the road but there is an extent to which the gadgets can extend to. Therefore, the use of a camera attached to traffic light module is proposed as a sensor since it can capture a wider range of traffic situation. It is expected that traffic situation captured by the camera is worked upon using some image processing algorithm to count the number of vehicles present on a particular lane. It is based on this number that the traffic controller makes a decision to what time to be allocated to each lane. In view of this, the scope of work is limited to developing an approach in which time allotment based on the traffic density measured is obtained. A novel mathematical algorithm is developed which is as described below:

The Time Control System: The time control which is the countdown timer is based on the following model. A value of 50 was chosen to be the difference in traffic density in which additional time will increment the chosen time. The chosen time is the time allocation (i.e $t_e$) when traffic on all lanes $T_p$ are equal or the difference in traffic between all lanes $T_{diff}$ is not greater than or equals to 50.

Time allocation denoted by $t_{alloc} = t_e$ at $T_e$ that is $T_{diff}$ not greater than or equals to 50

Note: $t_{alloc}$ refers to the countdown timer of the traffic controller

The $t_e$ chosen in this project is $\mathbf{2}\ \boldsymbol{minutes}$ (Note: It may be decided to be any value of desired choice).

$T_{diff}$ is the difference between traffic presence on a particular lane (denoted by $T_p$) and the lane having the minimum or the lowest traffic presence (denoted by $T_m$) as shown in equation (1).

$$T_{diff} = T_p - T_m \quad (1)$$

$T_m$ is identified by comparing all the $T_p$ 's and determine which lane has the lowest traffic presence.

For $T_{diff}$ greater or equals to 50, $t_{alloc}$ is made to be 50% increase in $t_e$ as given in equation (3).

$$t_{inc} = (\frac{50}{100}) \times t_e \quad (2)$$

$$t_{alloc} = t_{inc} + t_e \quad (3)$$

$t_{inc}$ is the value the $t_e$ will be incremented with which is obtained by calculating 50 per cent of $t_e$.

But since there may be further increment in 50, like the $T_{diff}$ may be 100 or 200, the multiples of 50 that can be found in $T_{diff}$ must be catered for and this is denoted by $T_{dm}$ which is given by equation (4)

$$T_{dm} = Rounded\_down\_value\_of(\frac{T_{diff}}{50}) \quad (4)$$

E.g. for a $T_{diff}$ value of 75, $T_{dm}$ = 1

Therefore, $t_{inc}$ will now be as expressed in equation (5)

$$t_{inc} = (\frac{50}{100} \times t_e) \times T_{dm} \quad (5)$$

$$t_{alloc} = t_{inc} + t_e \quad (6)$$

Looking at the mathematical model, it can be observed that it caters for when $T_{diff}$ is not greater than or equals to 50 as $T_{dm}$ will be zero (0) thereby making our $t_{inc}$ to be zero (0), then we have $t_{alloc} = 0 + t_e$ which will end up being 2 minutes.

The flowchart below depicts the mathematical algorithm detailed above:

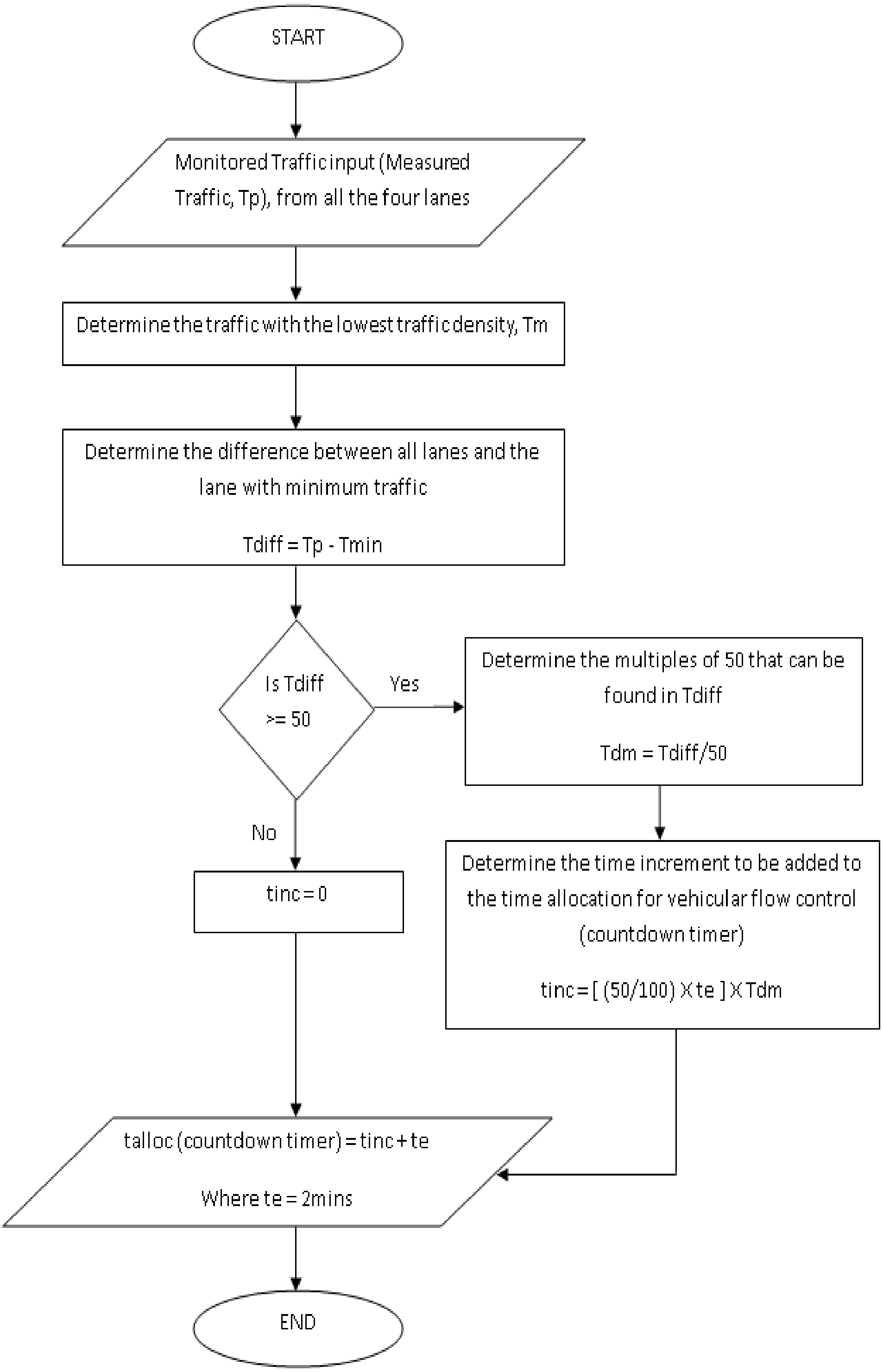


**Fig. 3.** Flowchart of the Time control model

## 3. Result Discussion

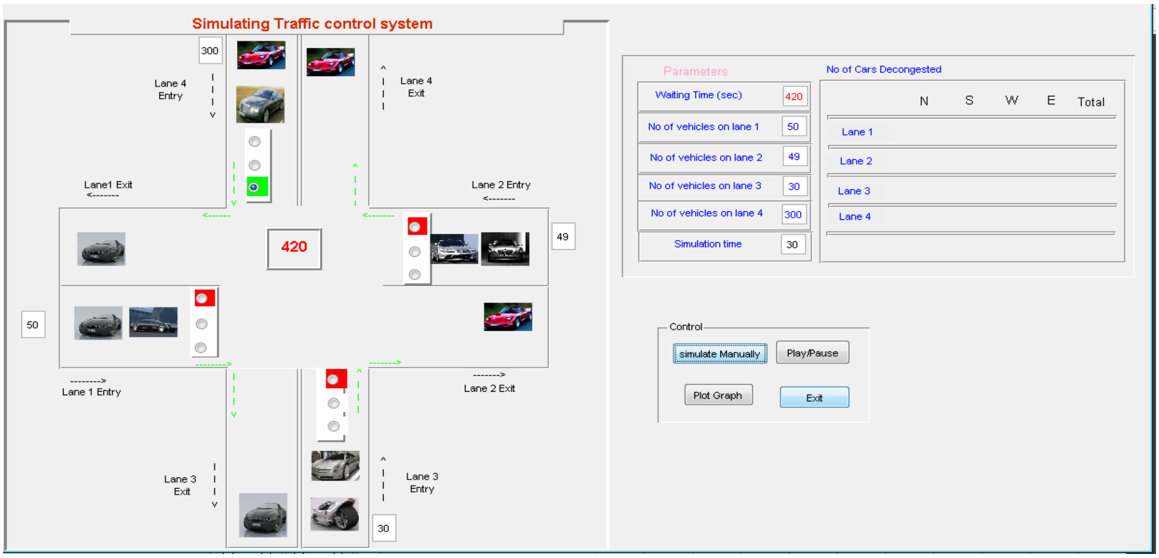


**Fig 2.** Simulation of the traffic decongested process depicting time allocation of 420 seconds

From the Figure 2 shown above, time allocation of 420 seconds (7minutes) was allocated to lane 4 which has a traffic presence ($T_p$) of 300. The lane with the lowest traffic presence ($T_m$) is determined which is 30. Then the difference in traffic presence ($T_p$) and the lowest traffic presence ($T_m$) is obtained as using the expression in equation (1).

$T_{diff} = T_p - T_m$ = 300 – 30 = 270. The multiples of the threshold value chosen, which is 50 ($T_{dm}$) is determined by equation (4)

$$T_{dm} = Rounded\_down\_value\_of\left(\frac{T_{diff}}{50}\right) = Rounded\_down\_value\_of\left(\frac{270}{50}\right) = 5$$

Time increment value is determined by the expression in equation (6)

$$t_{inc} = \left(\frac{50}{100} \times t_e\right) \times T_{dm} = \left(\frac{50}{100} \times 2\right) \times 5 = 5\text{minutes} \qquad (7)$$

The time allocation ($t_{alloc}$) is then determined by the expression in equation (7)

talloc = tinc + te = 5 + 2 = 7 minutes (420 seconds).

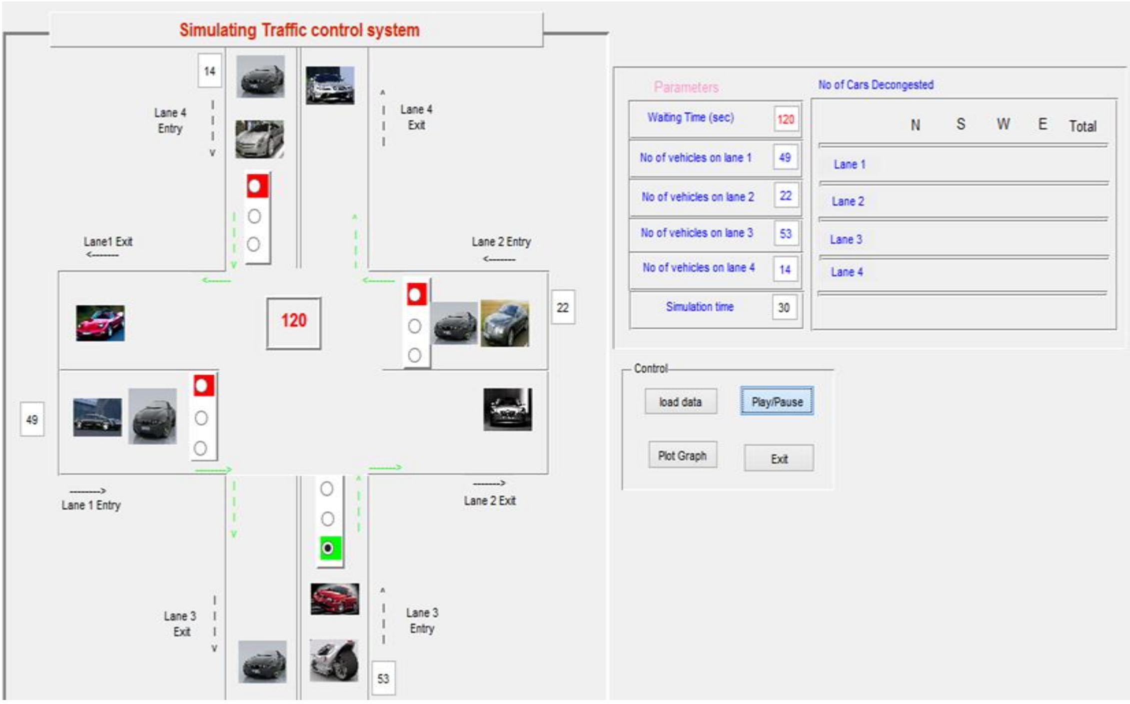


**Fig. 3.** Simulation of the traffic decongested process depicting time allocation of 120 seconds

Considering another of few instances of the simulation conducted which is shown in Figure 3; time allocation ( $t_{alloc}$ ) of 120 seconds (2 minutes) which is the time ( $t_e$ ) when traffic difference ( $T_{diff}$ ) between all the lanes are relatively the same based on threshold difference value of 50. The Traffic presence ( $T_p$ ) on lane 3 is 53. The lane with the lowest traffic (Tm) which is lane 2 has a traffic presence of 14. The difference between the $T_p$ on lane 3 and $T_p$ (the $T_m$ ) on lane 2 is 39; that is

$T_{diff} = T_p - T_m$ = 53 – 14 = 39

The number of 50's of the threshold value that can be found in the $T_{diff}$ (i.e $T_{dm}$ ) is determined which is 0; that is

$$T_{dm} = Rounded\_down\_value\_of\,(\frac{T_{diff}}{50}) = Rounded\_down\_value\_of\,\left(\frac{39}{50}\right) = 0$$

Then the time increment ( $t_{inc}$ ) is determined which is

$$t_{inc} = (\frac{50}{100} \times t_e) \times T_{dm} = (\frac{50}{100} \times 2) \times 0 = 0\text{minutes}$$

Therefore the time allocation ( $t_{alloc}$ ) is

$t_{alloc} = t_{inc} + t_e$ = 0 + 2 = 2 minutes (120 seconds)

Decongestion process as depicted in Figure 4 goes thus:

As shown in figure 3, all the four lanes are tagged North, South, East and West. It also shows the number of vehicles that is found on each lane. Because the difference on the four lanes is not up to 50, the standard 2 minutes (120seconds) is allotted.

The Figure 4 shows the number of vehicles decongested for all lanes over a simulation time of 10minutes. The North, the west and the south represent the other lanes other than the lane in focus which is considered the east.


**Fig. 4.** Traffic breakdown of the decongestion process

For total of 35 vehicles on lane 1, 11 vehicles were decongested northward, 10 vehicles southward, 4 vehicles to the west and 10 remained on the lane. Additional 6 vehicles became added leaving 16 vehicles on the lane.

For lane 2, a total of 36 vehicles was found, 8 vehicles were decongested to the north, 10 to the south, 9 to the west and 9 remained non-decongested (the east). Addition of 10 vehicles was added to the remaining making 19 left on the lane.

For lane 3, a total of 36 vehicles was also found, 10 vehicles were decongested to the north, 6 to the south, 10 to the west and 10 remained non-decongested. Addition of 29 vehicles was added leaving the lane with a new number of 39.

For lane 4, a total of 30 vehicles was found, 4 vehicles were decongested towards the north, 15 towards the south, 5 towards the west and 6 was left non-decongested. Additional 16 vehicles were added to make a new number of vehicles on the lane to be 24.

## 4. Conclusion and Recommendation

In this paper, the possibility of having a traffic control system to mimic the sixth sense of a human traffic controller is feasible. The mathematical model developed was able to assign more time to the lane with high traffic density so long it surpasses the set traffic density difference threshold.

However, since the basis for the model is to eliminate prolonged wait time especially for lanes with high traffic density, such things still results especially in the case where time allocation was 7 minutes (420 seconds). It is therefore recommended that in real live implementation of the algorithm, time allocation should not exceed a certain value even though the mathematical model calculates an appropriate time based on the traffic density. This is to curb the prolonged wait time that this developed model stand to mitigate. Also, it is recommended that the model should further be improved on by ensuring a mathematical algorithm is derived for choosing the percentage increase to be used in calculating time allocation for traffic control system rather than choosing an arbitrary value ( of 50% as used in this paper).

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