Real-Time Dynamic Traffic Light Timing Adaptation Algorithm and Simulation Software

D.T Dissanayake, S.M.R Senanayake, H.K.D.W.M.M.R Divarathne, B.G.L.T. Samaranayake
Dept. of Electrical and Electronic Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka
dilan.e04@ee.pdn.ac.lk, rajitha.e04@ee.pdn.ac.lk, menaka.e04@ee.pdn.ac.lk, lilantha@ee.pdn.ac.lk

***Abstract-* The main objective of this study is to design and implement a suitable algorithm and its simulation for vehicle detection to control road traffic. The system developed is able to detect moving metal objects (vehicles) and then to calculate the appropriate duration for the traffic signals at an intersection to operate. By employing mathematical functions to calculate the appropriate timing for the green signal to illuminate, the system can help to solve the problem of traffic congestion.**

The sensing element used to detect vehicles was a Magneto-Resistive sensor. The simulation of the algorithm of the traffic signal system was done using software. First stage of the hardware simulation tests were successfully performed on the algorithm implemented into a controller. Using the Graphical User Interface (GUI) developed, the operation of the traffic lights according to the new, calculated time can be observed. The new timing scheme that was implemented promises an improvement in the current traffic light system in terms of time save and track utilization and this system is feasible, affordable and more than that it is ready to be implemented with minimum changes to the current traffic system in Sri Lanka.

I. INTRODUCTION

Traffic congestion is a severe problem in many modern cities around the world. The existing systems in Sri Lanka, use timing circuits (Cycles) and mechanical timing switches to control the traffic lights. The timing on these circuits are decided on having some prior knowledge about the

- Average traffic flow patterns
- Average time to pass through the intersection etc.

Under this fixed time mode, the signal continuously cycles regardless of actual traffic demand.

As a solution to this problem, a system is proposed which count the number of vehicles entering the intersection from each direction and then the traffic lights are operated giving priority to the lane with the highest traffic density. This is an attempt to use an intelligent system, which replicates having a human controlling traffic, thus can avoid giving the green light to an empty road while motorists on a different route are stopped.

The paper is organized as follows: Section II describes the vehicle detection process. Section III is on the vehicle detection algorithm and the traffic light timing algorithm is presented in Section IV. Section V is on the traffic modeling software developed in the project to use in the system and Section VI presents the traffic signal simulator developed also in the same project to simulate the traffic when teaching modules before putting in operation. Section VII presents the results and discussion and the paper is concluded with proposed future work in Section VIII.

II. VEHICLE DETECTION

The main unit of the system is the vehicle detecting sensor which counts the number of vehicles that moves towards the intersection. There are many different ways for vehicle detection. One of the technologies, which are used today, consists of wire loops placed in the pavement at intersections. They are activated by the change of electrical inductance caused by a vehicle passing over or standing over the wire loop. Other than that, Infra-red object detectors, acoustic sensors etc can be used.

As for the vehicle detector in this project, HMC1052L Magneto resistive Sensor has been used, which is a product from Honeywell HMC series. The sensors task is to detect the presence of vehicles.

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Due to the fact that almost all road vehicles have significant amounts of ferrous metals in their chassis (iron, steel, nickel, cobalt, etc.), magnetic sensors are a good choice for detecting vehicles. The nature offers the earth's magnetic field that permeates everything between the south and north magnetic poles. So when a vehicle, that is a metal body, moves through the field, lines of flux bends. As the lines of magnetic flux group together (concentrate) or spread out (de-concentrate), a magnetic sensor placed nearby will be under the same magnetic influence the vehicle creates to the earth's field.

However because the sensor is not intimate to the surface or interior of the vehicle, it does not get the same fidelity of concentration or de-concentration and with increasing standoff distance from the vehicle, the amount of flux density change with vehicle presence drops of at an exponential rate. This has a very big advantage in vehicle detection as there is no false detection of a vehicle in an adjacent lane or vehicle in the adjacent parking spot. [4]

III. VEHICLE DETECTION ALGORITHM

The pattern of the change in earth magnetic field when a vehicle is moving is different for different vehicles, depending on the amount of metal the vehicle contains and the speed of the vehicle. Fig. 01, illustrates the quantized value of the of the output voltage of the sensor, as a bus was moving slowly. There is a sudden change in the magnetic field as the vehicle moves. By generalizing all the patterns obtained for different types of vehicles in different conditions, an algorithm has been developed to detect vehicles.

The algorithm has to be optimized such that one vehicle is counted only once and several vehicles moving together are detected separately. The Fig. 02, illustrates the change in the magnetic field as several vehicles move together.

By analyzing many such patterns for different vehicle types, an algorithm was developed to detect all types of vehicles including heavy vehicles, light vehicles, dual purpose vehicles, three wheelers and motor bicycles. This algorithm was implemented on to a controller and was tested on road.

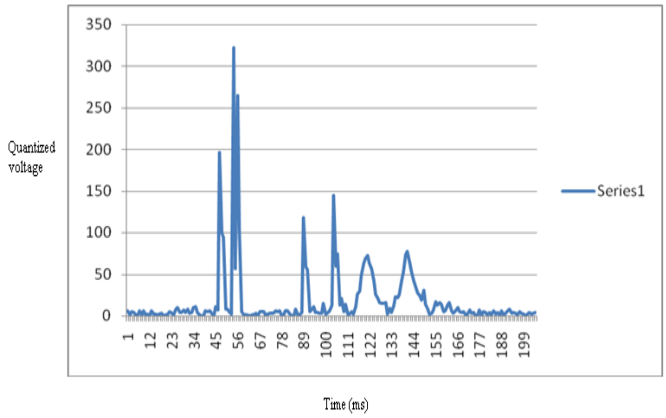


Fig. 1. Sensor output as a slow bus is moving nearby

The sensing units at each lane transmits the vehicle count of that lane to the central controlling unit periodically, which then calculates the optimum timing for the traffic lights to operate.

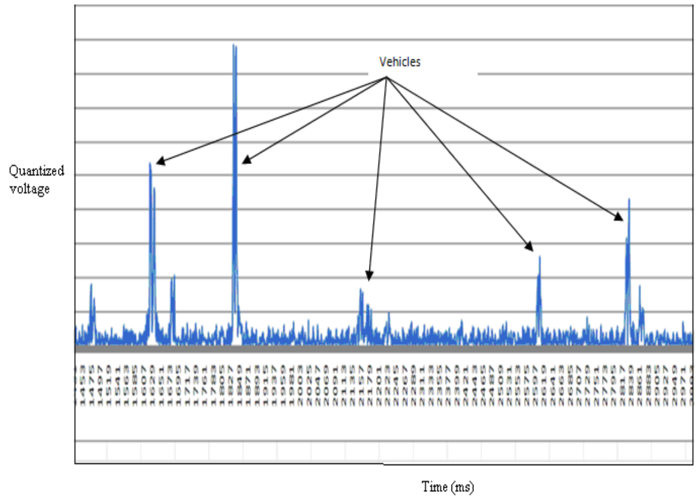


Fig. 2. Sensor output as several vehicles are moving

IV. TRAFFIC LIGHT TIMING ALGORITHM

The aim in designing and developing this intelligent traffic signal controller is to reduce the waiting time of each lane of the cars and also to maximize the total number of cars that can cross an intersection given the mathematical function to calculate the waiting time. There are several phases of operation in standard traffic models. For example, 2-phase systems, 3-phase systems etc. The Fig. 3 illustrates the two phases in the 2-phase operation. As it can be seen the 2-phase systems are only suitable for junctions with less percentage of right turns.

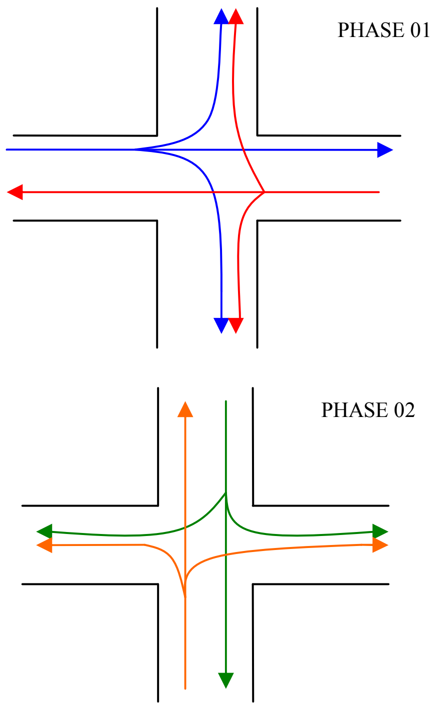


Fig. 3. 2-phase system

Our design was only limited to 2-phase systems, since 90% of the four way intersections in Sri Lanka are operated using this model. However it can easily be upgraded for 3-phase and 4-phase systems too.

Algorithm:-

Step 01: Through a field survey find the following parameters

- *lane width:* width of the lane at the intersection
- *Pedestrian flow for hour:* Usually at an intersection there is a pedestrian flow. This should be set as low (0-99), moderate (100-599), High(600-1199) , Very High(more than 1200)
- Percentage of right-turns, left-turns, straight-through in each lane.

Step 02: Calculating the Passenger Car Volume (PCV)

PCV = (Percentage of Heavy vehicles * 1.75) + (Percentage of buses*2.25)+(Percentage of light commercial vehicles*1.00)+(Percentage of mini-buses*1.25)+(Percentage of motor cycles*0.50)+(Percentage of cars* 1.00) (1)

Step 03: Define the all-red time, red-amber time.

All-red time is the time that all the red lights at the intersection are illuminating at the beginning of a timing cycle.

Red-amber time is the time that both the red and the amber lights are illuminating.

Step 04: Calculate the Critical Lane Volume (CLV)

CLV = Maximum value between sum of movements disturbing each other. (2)

This should be calculated for both phase 01 and 02.

Step 05: Calculate the cycle time using the standard 'Webster Formula' [1]

Cycle time C_0,

$C_0 = (1.5L+5) / [1-(\Sigma CLV_i / S)]$ (3)

S=1800 pcu/hour (for a 2-phase system)

L=lost time due to acceleration + all red time + red-amber time

Step 06: Calculate the effective green time

The time for the green light to illuminate at each phase.[1]

$g_i = [(C_0 - L) CL_i] / \Sigma CLV_i$ (4)

Where i=1,2 (i.e.,must be calculated for both phases)

Step 07: Calculate the actual green time

Actual green time is the effective green time minus the losses due to acceleration, all-red time, red-amber time.

$G_i = g_i - a_i + l_i$ (5)

Where i=1,2 l_i =loss time a_i =amber time

Step 08: Calculate actual the red time

$R_i = C_0 - (G_i + a_i + (a_i / l_i) CL_i$ (6)

V. TRAFFIC MODELLING SOFTWARE

A traffic modeling software was developed in-order to calculate the timing for the traffic lights to operate, using the standard 'Webster' formula and then to simulate the operation of the traffic lights in a Graphical User Interface. In order for the traffic modeling software to operate real time the central controller which receives the vehicle count was interfaced to the PC using the serial connector.

The Fig. 4, illustrates the interface to which all the data collected during the field survey (explained above) should be entered.

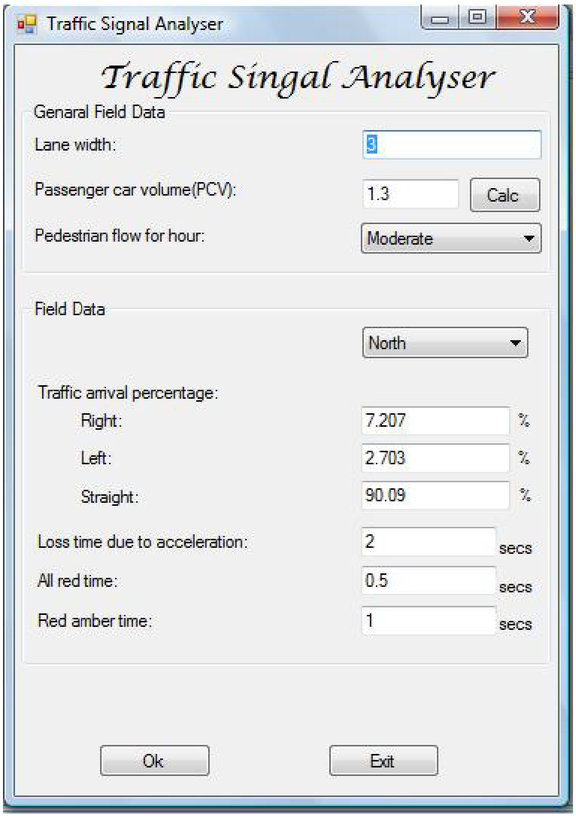
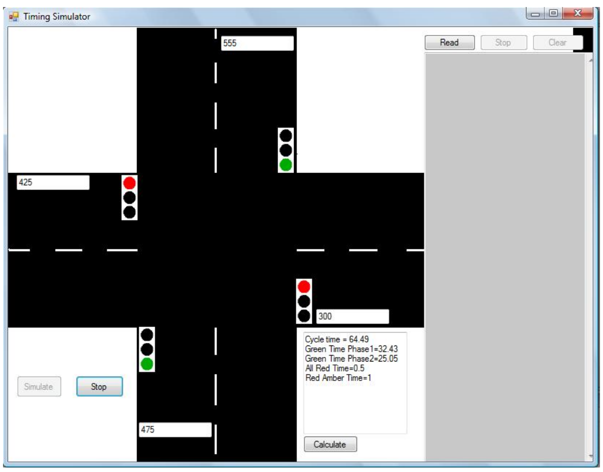


Fig. 4. Traffic Light Timing Analyzer- Data Entry Form

The pedestrian flow for hour can be selected from the entries in the drop down list as Low, Moderate, High, etc. The traffic arrival percentage for each lane can be entered by selecting the lane from the drop down list as North, South, East, West.

PCV can be calculated using the form that appears when the ***Calc*** button in the signal timing analyzer is clicked. After all the field data is entered the ***OK*** button is clicked which opens the traffic signal simulator.

VI. TRAFFIC SIGNAL SIMULATOR



The traffic signal simulator illustrates the change of traffic signal timing as it receives data from the central controller connected via the serial port.

Operation of the traffic signal simulator can be described in the following steps:

Step 01: 'Read' button.

Starts reading the serial port of the computer. All the controlling signals passed between the sensors and the central controller are displayed. When the vehicle count is received a message box is displayed prompting the user to calculate the traffic timing for the new values.

Step 02: Calculate' button

Calculates the optimum cycle time, green time and red time for the lights to operate. The resultant values are displayed.

Step 03: 'Simulate' button

Simulates the operation of traffic lights according to the new timing calculation.

VII. RESULTS AND DISCUSSION

Results obtained for the vehicle detection algorithm:

The vehicle detection algorithm developed is implemented in the microcontroller and it was tested on the road. The peaks shown in the Fig. 6 were detected as vehicles moving nearby by the microcontroller correctly.

Here, false vehicle detection can occur due to large magnetic field variation when a huge vehicle moves in the adjacent lane. But selecting proper threshold value, this effect can be reduced in the algorithm.

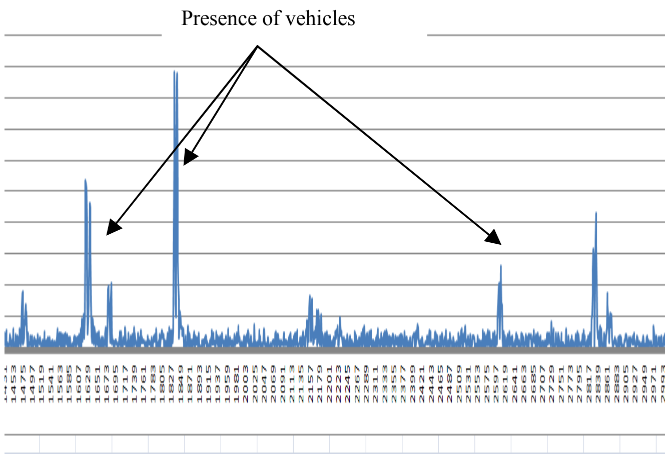


Fig. 6. Results obtained for the vehicle detection algorithm

Although natural changes in the earth magnetic field can also cause false, it was eliminated by using the generalized pattern for vehicle detection.

VIII. CONCLUSIONS & FUTURE WORK

The prototype of the intelligent traffic light system has successfully been designed and implemented.

Increasing the number of sensors to detect the presence of vehicles can further enhance the accuracy of the traffic light system. As to increase the reliability of the system, it is expected to introduce an automatic switch which changes to fixed time mode, during a failure of the dynamic traffic light system. Further, the traffic lights may turn off late at night when traffic is very light.

Another room of improvement is to have magneto resistive sensors replaced with an imaging system/camera system so that it has a wide range of detection capabilities, which can be enhanced and ventured into a perfect traffic system.

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