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A Novel High-Priority Traffic Light System Based on Microcontroller

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ABSTRACT

In the world today, traffic congestion in most cities is a severe problem. Recently, the system used is based on a fixed-time system in traffic which cannot provide incompetence if one or more lane has higher traffic than others. The higher traffic on one side lane needs a longer operation time for a green signal as compared to the fixed time-based systems. This paper proposed a High Priority Traffic Light system (HPTL) as a technique to compute the period time of green and red lights based on the density of traffic present at that time. To fix this problem an automatic traffic light control system should proposed. The proposed system will be achieved by using PIR (proximity Infrared Sensors). When the density is computed, the luminous period of the green and red signal will be selected to help the microcontroller. On each roadside, the sensors can detect the traffic density and calculate the vehicles in a specific lane then forward the density value to the microcontroller. The microcontroller will select the free lane and the high-traffic lane and then assign the priority system. The proposed system is successful in investing time, reducing vehicle density, and increasing reliability.

1. Introduction

The vehicle traffic density is increasing, and it is an alarming rate in most countries, which it is needs an intelligent traffic signal and replace the traditional manual and time-based traffic signal system. Experimental models in existence involve image processing-based vehicle density identification for routing of traffic which might be inefficient in situations like fog, rain, dust, etc.[1] Traffic congestion is a severe problem in most cities across the world and it has become a nightmare for the citizens. It is caused by delays in signals, inappropriate timing of traffic signalling, etc. The delay of the traffic light is hard coded and it does not depend on traffic. Therefore for optimizing traffic control, there is an increasing demand for a systematic quick automatic system.[2] To address the traffic issues, it is required more than just infrastructure expansion and building new roads. Managing traffic flow should be a combination of infrastructure, new technologies, and new ways of thinking [3]. In this paper, we present a new high-priority traffic light system based on multi-sensors that are connected directly to an Arduino microcontroller. The main contributions and innovations of this paper can be explained as follows:

- Develop the traditional traffic light system based on multi-sensors and microcontrollers.
- Simulate the proposed model in Proteus 8 and
- Built a prototype of HPTL and collected the timing sharing table for all directions.

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The rest sections of this paper are a short background of traffic light systems in section 2, the HTPL proposed model in section 3, simulation and testbed results in section 4, and the conclusion of the paper in section 5.

2. BACKGROUND

There are many researchers tried to improve the regular traffic lights based on different techniques. In this section, we present the trends which have been proposed and compare them with our proposed model.

In [3] the fuzzy logic system was proposed to optimize the traffic light system. The fuzzy logic system can optimize the period of green light based on the queue length and number of vehicles in each direction. The direction with longer lines can get longer green periods than other lines with fewer vehicles. An adaptive algorithm has been proposed in [4] to give priority to the road directions based on the waiting time and the queue's length, The adaptive algorithm reduces the waiting time of vehicles compared to a fixed time control algorithm, an algorithm that gives priority to the small queue and another algorithm prioritizes the largest queues.

In [5] authors proposed an intelligent traffic light controller for an emergency vehicle. The ambulance would have a transmitter within it, which would transmit a signal to the receiver side, this will enable a green signal in the corresponding pole. The light of the signal is controlled by automatic timers which are built in by discrete components. Arduino boards are used to control the automatic timers. This module helps to save the lives of many people as well as to avoid congestion. In [6] authors implement a microcontroller-based traffic light system for road intersection control.

The traffic light system is designed using Programmable Integrated Circuit (PIC) 16F84A microcontroller, power section, crystal oscillator, and light emitting diode (LED). An infrared sensor is used in [7] to scan the road and send SMS to vehicles to choose another road and the mobile company can re-arrange the time of the output signals for Red, Green, and Yellow based on the vehicle density if all roads are crowded. For emergency cases, the authors in [8] proposed a new system based on Bluetooth to communicate with the traffic light and adjust the green signal time.

In smart cities author [9] proposed hierarchical fuzzy logic systems to arrange the traffic light signals, Multi-sensors were used and the vehicle density on each road will be calculated and the decision will of the fuzzy system controls the traffic light signals. In [10] authors used an IR sensor and PIC controller to compute the vehicle density and evaluate the road status. Four side junction was used and simulated the traffic light model, The proposed model used IR sensors and an Arduino microcontroller because the implementation and programming are simpler than using PIC also the time response is high.

3. HPTL SYSTEM MODEL

This section presents the proposed HPTL model it has the following main stages:

Stage 1: Calculate the direction of vehicle density based on the two sensor values in the road direction.

Stage 2: Calculate the direction index sensor value and compute the direction weighted value.

Stage 3: Apply the priority algorithm and compute the green time in each direction

Stage 4: Implement the new period for traffic light signals.

Fig.1 shows the proposed steps

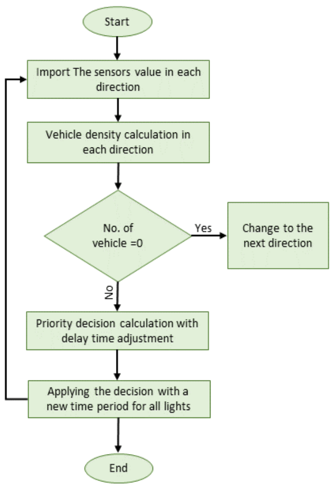

Fig. 1. HTPL stages

In each road direction, there are two sensors, the sensor values can be 00, 01, 10, and 11, and the index will be high if both sensors are high (high vehicle density in this direction). We can define the index as mentioned in the following: -

$$\mathrm{As} = \begin{cases} 1, & \text{A sensors are high} \\ 0, & \text{others} \end{cases} \tag{1}$$

$$\mathrm{Bs} = \begin{cases} 1, & \text{B sensors are high} \\ 0, & \text{others} \end{cases} \tag{2}$$

$$\mathrm{Cs} = \begin{cases} 1, & \text{C sensors are high} \\ 0, & \text{others} \end{cases} \tag{3}$$

$$\mathrm{Ds} = \begin{cases} 1, & \text{D sensors are high} \\ 0, & \text{others} \end{cases} \tag{4}$$

Where: As, Bs, Cs, and Ds are the index values for all directions. The total index value (D) for all directions is the sum of all values.

$$D = As + Bs + Cs + Ds \tag{5}$$

The total weighted will be=1 and the direction weight for all roads (A, B, C, and D) as shown:

$$W = w1 + w2 + w3 + w4 \tag{6}$$

$$w1 = \begin{cases} 25\%, & D = 0 \\ \frac{As}{D}, & others \end{cases} \tag{7}$$

$$w2 = \begin{cases} 25\%, & D = 0 \\ \frac{Bs}{D}, & others \end{cases} \tag{8}$$

$$w3 = \begin{cases} 25\%, & D = 0 \\ \frac{Cs}{D}, & others \end{cases} \tag{9}$$

$$w4 = \begin{cases} 25\%, & D = 0 \\ \frac{Ds}{D}, & others \end{cases} \tag{10}$$

For the case of D=zero, that represent the vehicle density approximately distributed in all direction equally i.e. (all directions have low vehicle density with index =0). In this case no need to activate the priority system and the period = 25% in each direction. For $D \neq 0$, the priority system will calculate the weight for all directions and apply the HPTL system algorithm as shown in algorithm 1.

Algorithm 1: HPTL Implementation

Initialize
T← total traffic light time
N← number of roads
begin
Repeat
Read sensors value
For *i=1 to N* ***do***
Calculate the sensor index for all sensor roads;
Calculate the weights;
*Green led(i)=w(i)*T*
end For
end

4. Simulation and Testbed Result

This section presents the proposed system design and the evaluation results in the simulation program and the prototype circuit.

4.1 Proteus design

HPTL system was designed using 8 IR sensors and an Arduino micro as a microcontroller. This microcontroller is easy to implement in prototypes at a low cost [11].

Four direction junctions have been taken in this design, in each direction, there are two sensors. The high value of sensor output represents there is a vehicle in this road section. For both sensors, the high value of 1st sensor and also high for the 2nd sensor will indicate the density is high. For these four directions, the total number of cases is 16 because the system tries all possible cases based on the binary condition. Fig.2 illustrates the junction environment in the simulation program and Fig.3 shows the circuit diagram of the proposed system.

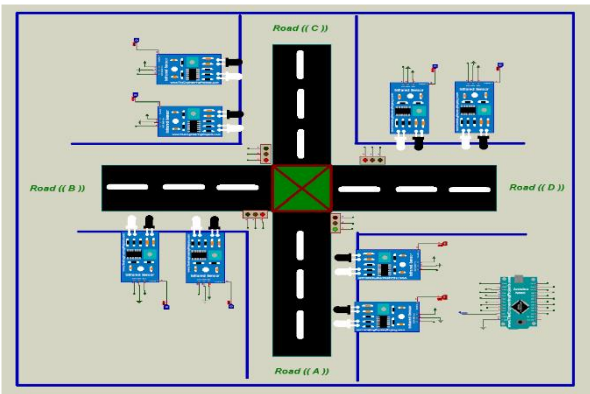

Fig. 2. System design with sensors

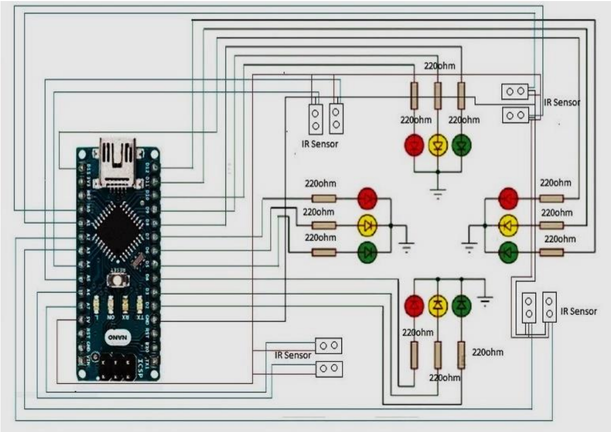

Fig. 3. HPTL Circuit diagram

4.2 Prototype Circuit

This subsection presents the testbed prototype circuit using 4 IR sensors, an Arduino Uno microcontroller, connections, and LEDs. Fig. 4 shows the traffic light system for four directions, and Fig. 5 shows the case if the density is high in one direction, the green signal will be on based on the priority proposed system

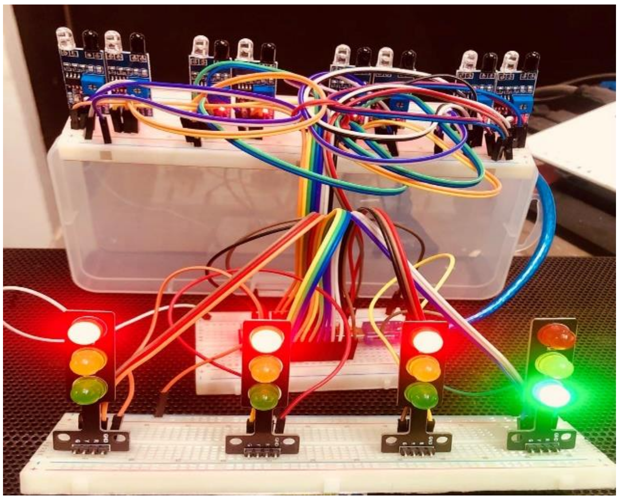

Fig. 4. Prototype Circuit

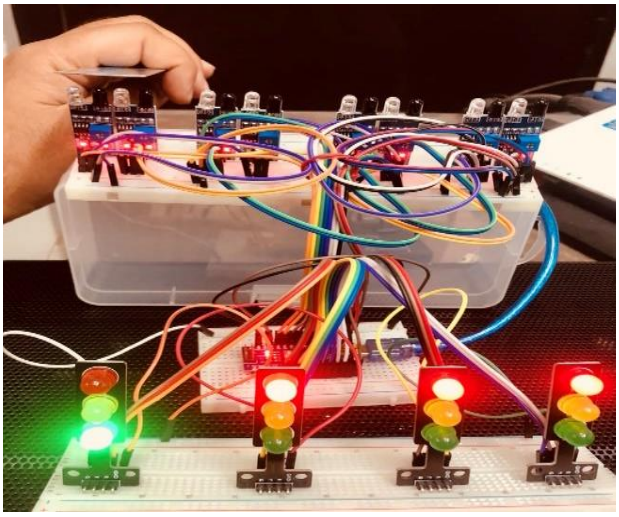

Fig. 5. Prototype Circuit with priority implementation

4.3 Total results

The running time used in this experiment is 120 seconds for all cases, the green signal time will be calculated based on the weight value for each direction. Fig.6 shows the snapshot of microcontroller output for case 1 and case 2. calculations for all cases are illustrated in Table 1

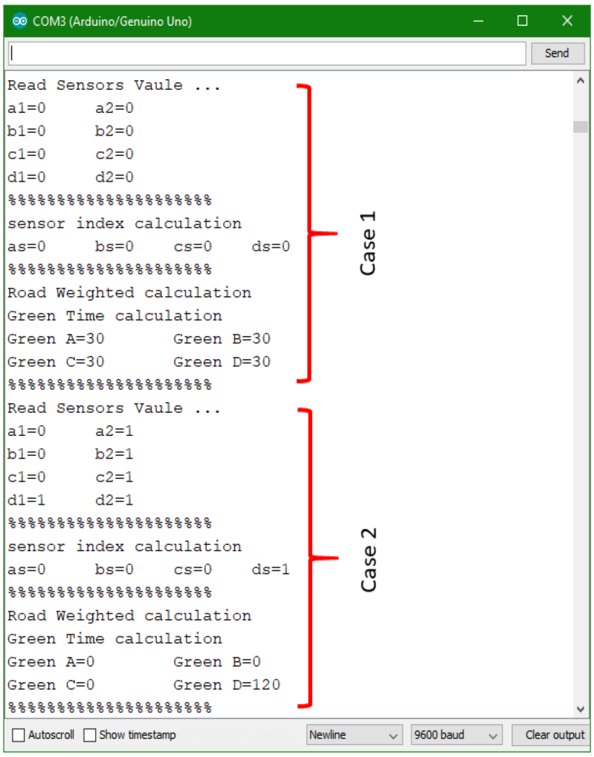

Fig. 6. Snapshot of Arduino Serial Monitor

Table 1. Total Decision Weighted results

CASE	Road Sensor Values				Decision Weighted values (W)				Final Decision
	As	*Bs*	*Cs*	*Ds*	w1	w2	w3	w4	
Case 1	0	0	0	0	25%	25%	25%	25%	All Roads with the same priority
Case 2	0	0	0	1	0%	0%	0%	100%	Road D has full priority.
Case 3	0	0	1	0	0%	0%	100%	0%	Road C has full priority.
Case 4	0	0	1	1	0%	0%	50%	50%	Road C&D shares the priority.
Case 5	0	1	0	0	0%	100%	0%	0%	Road B has full priority.
Case 6	0	1	0	1	0%	50%	0%	50%	Road B&D shares the priority.
Case 7	0	1	1	0	0%	50%	50%	0%	Road B&C shares the priority.
Case 8	0	1	1	1	0%	33.3%	33.3%	33.3%	Roads B, C, and D share the priority.
Case 9	1	0	0	0	100%	0%	0%	0%	Road A has full priority.
Case 10	1	0	0	1	50%	0%	0%	50%	Road A&D shares the priority.
Case 11	1	0	1	0	50%	0%	50%	0%	Road A&C shares the priority
Case 12	1	0	1	1	33.3%	0%	33.3%	33.3%	Roads A, C, and D share the priority.
Case 13	1	1	0	0	50%	50%	0%	0%	Road A&B shares the priority.
Case 14	1	1	0	1	33.3%	33.3%	0%	33.3%	Roads A, B, and D share the priority.
Case 15	1	1	1	0	33.3%	33.3%	33.3%	0%	Roads A, B, and D share the priority.
Case 16	1	1	1	1	25%	25%	25%	25%	All Roads with the same priority

As mentioned in Table 1, the priority will be the same (no priority for specific roads) in Case 1 and Case 16 because the road density is equal. The other Cases give priority according to the weighted value. The priority will shared for the high value of sensor recorded.

The collected results have been divided into four groups. Group 1 represents the result of Case 1, Case 2, Case 3, and Case 4 as illustrated in Fig.7. The green signal time of Case 1 is 30 seconds for each direction (equally time sharing) because the sensor index because the sensor index value for each direction is equal to 0. In case 2 road D has high vehicle density, the green signal time will be 120 seconds and the rest directions wait for 120 seconds to read their sensors again, same scenario in case 3 for road C. In case 4 the green signal time will divided by two because the two directions have equal density (high density compared with the other two). Group 2 shows the results of Cases 5, 6, 7, and 8. The result of Group 2 is shown in Fig. 8. The priority of road B is 100% in case 5, in case 6 and case 7 the priority will share 50% between B, D in case 6 and B, C in case 7. The high traffic in case 8 was illustrated on three roads (B, C, and D), so the time will be shared among them. We can see the weighted table has been implemented in all cases in Group 3 and Group 4 as shown in Fig.9 and Fig. 10 respectively. Finally, By focusing on the last case, when all index values = 1 (case 16 in Fig.10), the high density in all directions so all roads have the same priority (normal case as regular system).

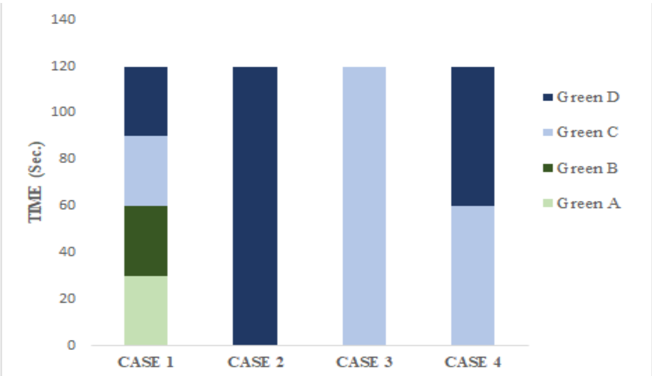

Fig. 7. Group 1 Green signal time

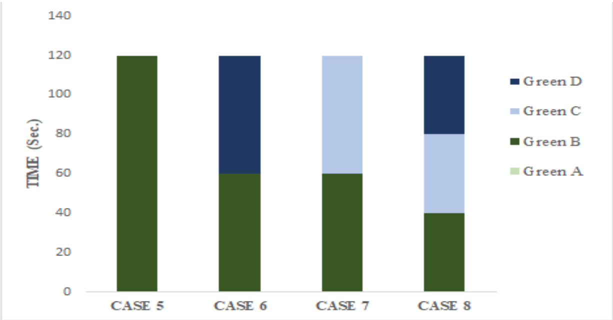

Fig. 8. Group 2 Green signal time

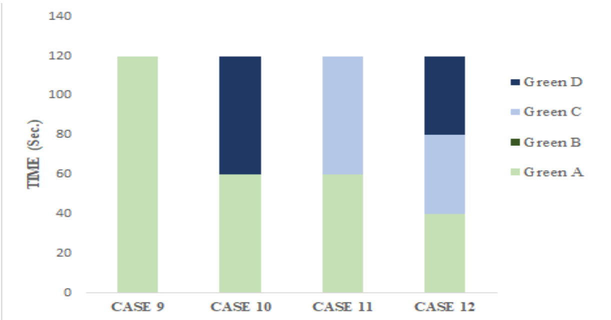

Fig. 9. Group 3 Green signal time

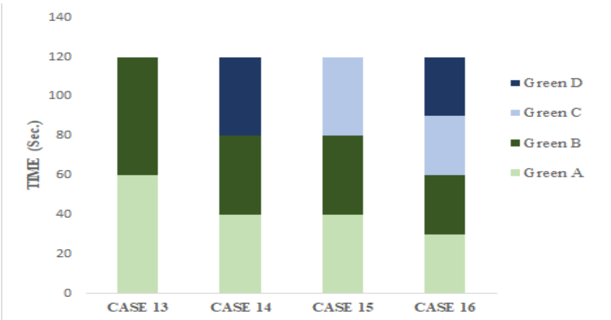

Fig. 10. Group 4 Green signal time

5. CONCLUSION

High Priority Traffic Light system (HPTL) was proposed in this paper to optimize the high traffic problem, HPTL system success in the simulation test and the prototype also. The real-time simulation shares the period-time of green signals among all roads based on the proposed priority conditions. The prototype setting time is 120 seconds; all cases have been tested and compared them with real-time simulation. The simulated result and prototype results are the same. The recommendation for future work is to improve this system using more than two sensors per road to increase the system sensitivity.

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