Design and Fabrication of a Smart Traffic Light Control System

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Abstract: - Although the importance of traffic lights which give safety to the users on roads, the traffic jam causes great loose in time and energy (fuel) for some people, while others crossing road or roundabout have no traffic jam. The main objective of this paper is to design and implement a suitable algorithm and its simulation for an intelligent traffic signal simulator. The system developed is able to sense the presence or absence of vehicles within a certain range by setting the appropriate duration for the traffic signals to react accordingly. 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 reason depends on resent fixed programming time. So, our target in this paper is to make this time unfixed according to the size of traffic jam, When there is a traffic jam in any road the green light which means permeation gives full time to the user of the road. If there is no traffic jam, the green light does not give full time, but it gives programming time. The new timing scheme that was implemented promises an improvement in the current traffic light system and this system is feasible, affordable and ready to be implemented especially during peak hours. In general, the system works adequately, as foreseen in the design process.

Key-Words: - Traffic lights, PLCs, Lab VIEW, Matlab, Sensors

1 Introduction

Traffic lights aren't all that bad. And cities all around the world have done their part to make it easier for drivers to get to one point, with a few wait times here and there. But, if you've been driving at "odd times" of the day, then you've probably learned that sometimes you won't always see the lights turn as quickly as you want them to. Many traffic light systems operate on a timing mechanism that changes the lights after a given interval. An intelligent traffic light system senses the presence or absence of vehicles and reacts accordingly. The idea behind smart traffic systems is that drivers will not spend unnecessary time waiting for the traffic lights to change. A smart traffic system detects traffic in many different ways. The older system uses weight as a trigger mechanism, Current traffic systems react to motion to trigger the light changes, The more number of drivers who know about the operation of traffic signals, the less frustrated they are going to be while waiting for the lights to change. Recent technology utilization is video detection. A camera feeds a small computer that can "see" if a vehicle is present. The older system uses weight as a trigger mechanism. Current traffic systems react to motion to trigger the light changes. Once the infrared object detector picks up the presence of a car, a switch causes the lights to change. In order to accomplish this, algorithms are used to govern the actions of the traffic system. While there are many different programming languages today, some programming concepts are universal in Boolean Logic. We need to understand the function of traffic signals so that we can improve driving habits by controlling the speed in order to reduce the number of associated traffic accidents. The more number of drivers who know about the operation of traffic signals, the less frustrated they are going to be while waiting for the lights to change. The main aim in designing and developing of the Smart Traffic Signal Simulator 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. The traffic signal system consists of three important parts. The first part is the controller which 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. The second part is the signal visualization or in simple words is signal face. Signal faces are part of a signal head provided for controlling traffic in a single direction and consist of one or more signal sections. These usually comprise of solid red, yellow, and green lights. The third part is the detector or sensor. The sensor or detector is a device to indicate the presence of vehicles. 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. Recent technology utilization is video detection. A camera feeds a small computer that can "see" if a vehicle is present

2 Experimental Setup

In order to implement the Smart Traffic Signal Simulator, one needs to setup and assemble the hardware components and write a program to control the smart traffic signal simulator. The layout of the Smart Traffic Signal Simulator is displayed in Figure 1. The blocks, which are labelled N1, N2, N3, E1, E2, E3, S1 and W1 are the infrared object detectors.

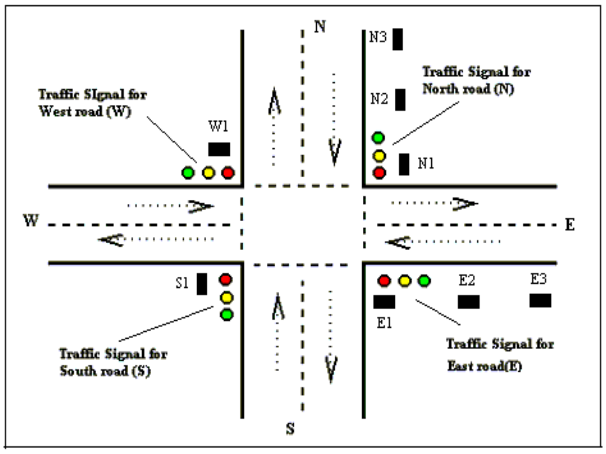

Fig.1 Smart traffic signal simulator layout

2.1 Hardware Components

The traffic light system consists of four important components: the controller which is the brain to the system, the sensors which detect the presence of vehicles, the light emitting diodes (LED) which act as the actuator and the countdown timers which is displayed in Lab VIEW. The programmable logic controller PLC is used as the controller of the traffic signal. The PLC, which needs to be plugged to the system, is directly attached to the computer in order to program it. The wiring for the output and input signals is done from PLC. Figure 2 shows the CPU222 of the S7-200 PLC to which a 12V DC power is supplied. There is also a DB9 connector, that is connected to the COM port of computer using RS-232 serial cable, for S7-200 PLC programming and serial communication during run-time. Next to the S7-200 PLC, there is a breadboard. As for the infrared object detector, SHARP GP2D15 is used. The sensor task is to detect the presence of vehicles. It is functioning continuously by giving a logic 0 when there are no vehicles and logic 1 when there are vehicles present. Therefore, they can detect the length of the queue depending on where they are placed. Each detector has a JST connector housing slot and three crimped wires to use in the JST connector. The connectors are plugged into the appropriate housing slot and into the detector. The light emitting diodes are used in order to show the traffic light changing according to the program. The LED light will change according to output by the S7-200 PLC. In each lane, there are three LEDs according to traffic lights colours which consist of red, yellow and green. Moreover, two inverters were used in order to connect the output of green and red LEDs together. Therefore, when the green LED is ON then the red LED will be OFF and vice-versa. Figure 3 shows the connection of the input and output ports to sensors and LEDs. The S7-200 PLC has 16 Input and Output ports. The ports were divided into 8 input and 8 output ports. The output ports, which are from P0 to P7, give either logic 0 or 1 to the LEDs. Meanwhile, the input ports, which are from P8 to P15, receive input signal from the sensors.

Fig.2 The CPU222 of the S7-200 PLC

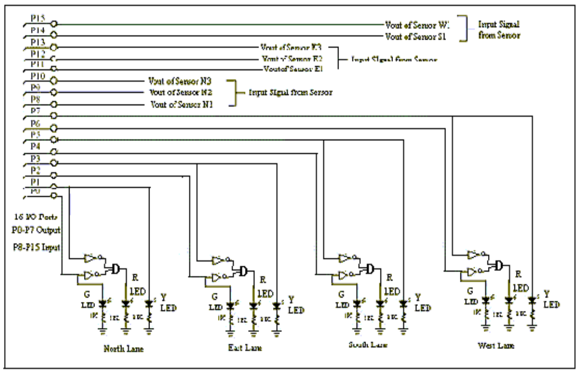

Fig.3 Connection of the input and output ports to sensors and LEDs

ISBN: 978-1-61804-131-9

2.2 Software Simulation

After the hardware had been setup, a program written in the S7-200 PLC programming language in the editor is downloaded into the PLC. The simulation of the algorithm of the traffic signal system was done using Matlab software. Furthermore, the countdown timer interfacing according to the traffic system using Lab VIEW software is created using the BNC Adapter and the Data Acquisition Card (DAQ) device. The Lab VIEW programming is done in the diagram using graphical source code. In the block diagram the program runs from left to right. If the green light in the traffic model does not illuminate, the system goes into default since there is no input into the system. The signal from the sensor is acquired through the DAQ, which is connected, to the computer.

3 Implementation

A single 3-lamp traffic light is considered as a finite state machine. It has three states, Red, Yellow, and Green, which are also the outputs. A single input for the traffic light is defined, with values 0 for no change and 1 for change. This input is connected to the output of a countdown timer, which outputs a 1 when it reaches zero. Thus for a single light, we can draw the state transition diagram as shown in Figure 4.

NS	**0**	**1**
R	R	G
Y	Y	R
G	G	Y

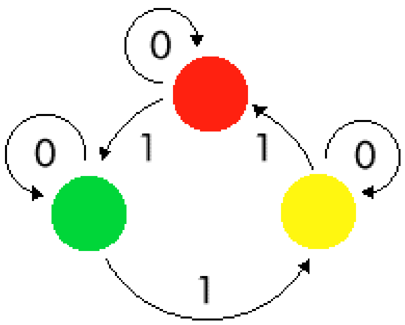

Fig.4 Traffic Signal Sequence

A single traffic light is not very useful. In reality, lights are installed in pairs, with two pairs per intersection. Therefore, in the simulation one pair of lights was used to control traffic in the north-south direction, while the other pair controls the east-west direction. Furthermore, the two pairs of lights must be synchronized; therefore countdown timers are connected to the lights in pairs. Since the lights that make up a pair mirror each other, they are considered as a single light. But since the opposite pairs must be in sync, we must group their different outputs together. Thus there are 3 × 3 = 9 possible outputs. Each combined output describes the colour of the north-south light along with the colour of the east-west light. In order for the Traffic Signal Simulator to work intelligently, mathematical functions that can calculate the time needed for the green signal to illuminate based on the length of queue are developed. The length of queue is detected through the infrared object detectors by the presence of vehicles. The timing for the green signal to illuminate is given by:

$$time = \frac{1}{3}\left(\frac{d}{v_1} + \frac{a_a}{v_s} + z\, D_{12}\right) \qquad (1)$$

where d is the distance between one sensor to another sensor in (m), v_1 is the average speed of the first car moving from stationary at the moment the signal turned green in (m/s), a_a is the average acceleration of a car from stationary position to the next car position in (m/s^2), v_s is the average speed of a car moving from standstill after traffic light turns green in (m/s), z is a variable, which gives two values only: 0 when there is no sensor triggered and 1 if there is at least one sensor triggered, D_{12} is the total time delay given by:

$$D_{12} = t_1 (n_t - 1) + t_2 \qquad (2)$$

where t_1 is the value of the first time delay in (s), n_t equals to the number of sensors triggered, and t_2 is the second time delay for each lane in (s). The first step in the simulator implementation is to install the hardware components. The connection of the S7-200 PLC, infrared object detector, light emitting diode (LED), AND gate and inverter gate should be wired correctly. Then the program codes that had been developed simultaneously are downloaded to the S7-200 PLC. In each lane, three infrared object detectors have been installed. Therefore, the program will check first the condition of the sensors, whether they are triggered or not. The total number of sensors triggered will be used in the mathematical function to calculate the appropriate timing for the green signal to illuminate. After the green signal finishes the illumination timing, the yellow signal will illuminate for 2 seconds and then finally the red signal will illuminate. After that, the traffic signal will wait for 1 second before it goes to the next lane condition.

4 Results and Discussions

The traffic signal operation will start by the traffic lights illuminating in red for 1 second in all

ISBN: 978-1-61804-131-9

directions. Then the traffic signals will start illuminating in the clockwise direction of the magnet compass. This means that it will start operating in the North lane, then East lane, then South lane, then West lane and goes back to North lane. After the starting condition, the simulator will check the North lane condition. It will check whether the sensors are triggered or not. The total number of sensors triggered will be used in the mathematical function to calculate the appropriate timing for the green signal to illuminate. After the green signal finishes the illumination timing, the yellow signal will illuminate for 2 seconds and then finally the red signal will illuminate. After that, the traffic signal will wait for 1 second before it goes to East lane condition where the same check is performed before going to the south lane etc. Two displays where generated by Lab VIEW programming. The first is the front panel for the user interface and the other is the block diagram that contains the graphical source code that defines the functionality of the VI. The front panel for the current work is shown in the figure 5.

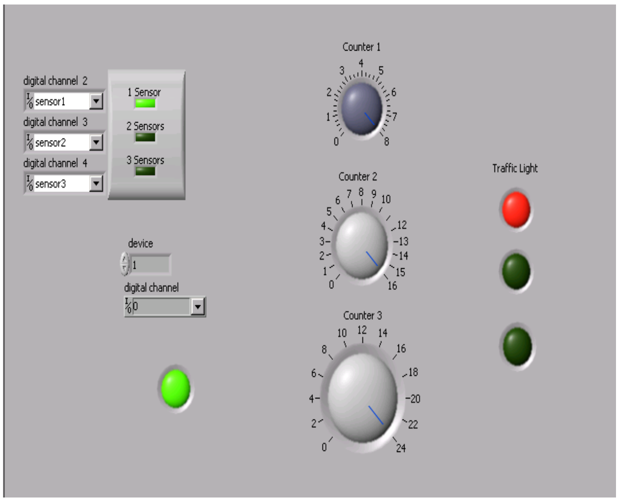

Figure 5: Front panel of counters

As it can be seen in Figure 5, when one sensor is activated, Counter 1 will start counting down till it reaches zero. When the counter stops at zero, the traffic light will automatically shift from green to red coinciding with the traffic light on the traffic system model. Since the sensor only detects a presence of a single vehicle, therefore the counter will start counting downwards from 8 seconds to zero. If two sensors are triggered saying there are two vehicles, then Counter 2 will be activated and will start counting down from 16 seconds all the way to zero. This process is the same for three sensors triggered by the vehicles that will count down from 24 seconds to zero. The programming is done in the diagram using graphical source code. In the block diagram the program runs from left to right. If the green light in the traffic model does not illuminate, the system goes into default since there is no input into the system. The three different cases, where the sensors are triggered, are represented in the following different block diagrams.

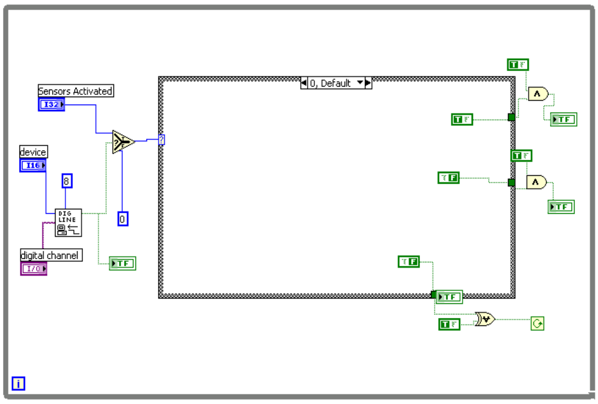

Figure 6: Default Situation

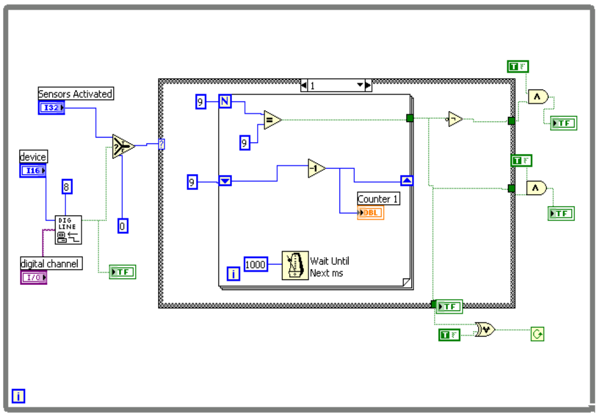

Fig.7 Situation where only 1 sensor is triggered

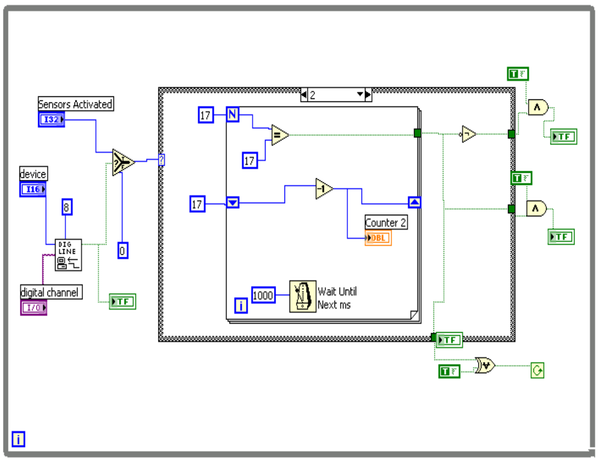

Fig.8 Situation where 2 sensors are triggered

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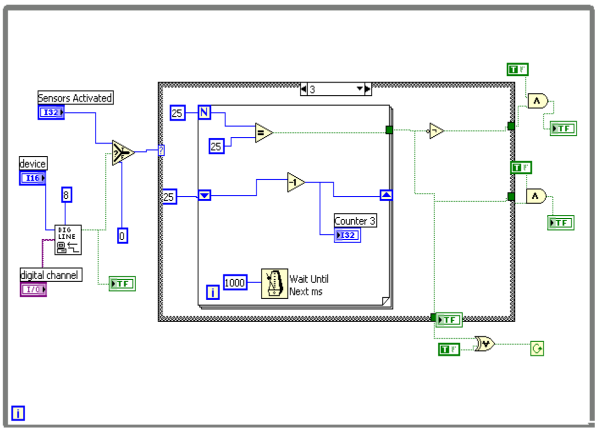

Fig.9 Situation where 3 sensors are triggered

In this work several infrared sensors were used to detect the presence of vehicles in all four directions. This functions as when a vehicle blocks the sensor at a certain distance, the sensor is triggered and this will inform the S7-200 PLC that there is a vehicle in the specific lane.

A while loop is used for the three cases of the block diagrams describing the three different conditions. The inner square contained in the while loop is called the case structure. The current design of a traffic light system in terms of mechanical, electrical, logic and instrumentation aspects takes full advantage of the application of sensors in the real life situation of traffic flow by optimizing the time between light changes. If there are no vehicles on the road in all four directions, then the lights will change from green to yellow in 2 seconds and from yellow to red in another 2 seconds.

This process goes on in a cycle from the North lane, followed by the East lane, South lane and lastly the West lane. For example, if there are 2 vehicles on the North lane then the time taken from the green light to shift to yellow is 16 seconds. That goes equally for all the other lanes.

In the model made, each vehicle represents several vehicles; therefore if there is 1 vehicle blocking the sensor placed at the sides of the road then the sensor will be triggered and informs the S7-200 PLC that there are vehicles in those specific lanes. The smart traffic light that had been developed presents several advantages. Since the waiting time of the vehicles for the lights to change is optimal, the emission of carbon monoxide from the vehicles is reduced. This will give a positive effect to the green house effect towards the environment.

The smart traffic system will also save the motorists' time and reduces their frustration while waiting for the lights to change since it helps reducing congestion in the traffic intersections. Another advantage is that there is no interference between the sensor rays and there is no redundant signal triggering. By being able to interface with the Lab VIEW software, the sensor based traffic system will easily accept feedback. Therefore there can be communication between the software and the hardware.

4 Conclusion

A smart traffic light system had successfully been designed and developed. The sensors were interfaced with Lab VIEW integrated system. This interface is synchronized with the whole process of the traffic system. This prototype (Figure 10) can easily be implemented in real life situations. The developed software also works well as the interface between the traffic controller hardware with the traffic sensors and the traffic expert. The software can be used to perform traffic data interchange and it enables the proposed smart traffic controller system to realize several traffic flow optimization strategies at a single or network junction. The design of the traffic light system can be further enhanced by increasing the number of sensors to detect the presence of vehicles. Another room of improvement is to have the infrared 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.

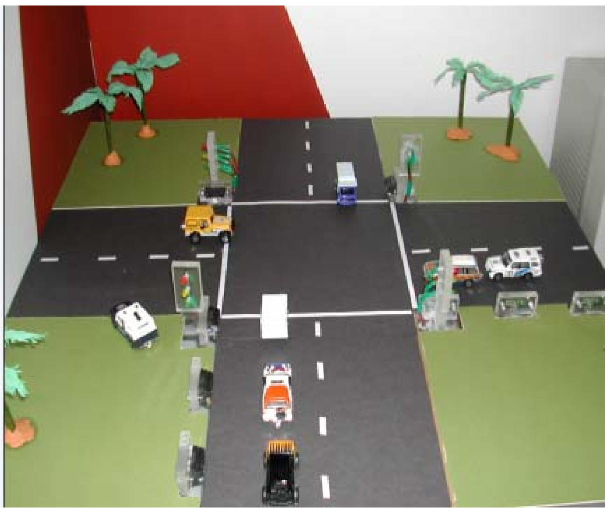

Fig.10 Model of the traffic system

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