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Development Of An Intelligent Traffic Control System With Backtracking

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Abstract

Fast road transportation systems are the key factors which influence the economic and industrial development of any country. Traffic congestion is an increasing problem in cities and suburbs such that suburban commuters now spend more time commuting to their work, schools and social events. Existing timer automated traffic control systems has considerably contributed to some of the problems of time wasting since vehicles have to wait at intersections, even though there is little or no traffic in the other direction. In this work, an attempt was made to develop an intelligent traffic control system with the ability to monitor and automatically pass the lane with more vehicles while also keeping track of the other lanes with fewer vehicles so as not to keep the vehicles in those other lanes waiting longer than necessary. The design was focused on sensing the traffic level on each of the lanes of the road depending on the density of each lane using Light Dependent Resistors (LDR) sensors. The arrangement of the sensors on the road layout was positioned to perform this function. For each lane of traffic to be controlled, four sensor arrays was deployed and arranged in an array of four, two transmitters and two receivers. The whole system was trained using decision tree algorithm in order to adapt to real time processing at the intersections. The testing of the project was carried out in an open field where there was little or no shades. The system was able to provide the quickest possible clearance to vehicular traffic in all directions at a junction, as well as monitor, regulate and pave way for vehicles on congested lanes while keeping track of the other lanes. Intelligent traffic control systems can be improved by training the system to adapt to real time processes using decision tree, a type of machine learning algorithm used for classification problems.

Keywords: *Transportation, Light Dependent Sensor, Algorithm, Traffic Control, Machine Learning.*

1. Introduction

Fast road transportation systems are the key factors which influence the economic and industrial development of any country. Traffic congestion is an increasing problem in cities and suburbs such that suburban commuters now spend more time commuting to their work, schools and social events. Existing timer automated traffic control systems has considerably contributed to some of the problems of time wasting since vehicles have to wait at intersections, even though there is little or no traffic in the other direction. In this work, an attempt was made to develop an intelligent traffic control system with the ability to monitor and automatically pass the lane with more vehicles while also keeping track of the other lanes with fewer vehicles so as not to keep the vehicles in those other lanes waiting longer than necessary.

The design was focused on sensing the traffic level on each of the lanes of the road depending on the density of each lane using Light Dependent Resistors (LDR) sensors. The arrangement of the sensors on the road layout was positioned to perform this function. For each lane of traffic to be controlled, four sensor arrays was deployed and arranged in an array of four, two transmitters and two receivers. The whole system was trained using decision tree algorithm in order to adapt to real time processing at the intersections.

The testing of the project was carried out in an open field where there was little or no shades. The system was able to provide the quickest possible clearance to vehicular traffic in all directions at a junction, as well as monitor, regulate and pave way for vehicles on congested lanes while keeping track of the other lanes.

Intelligent traffic control systems can be improved by training the system to adapt to real time processes using decision tree, a type of machine learning algorithm used for classification problems.

2. **LITERATURE REVIEW**

2.1 Traffic Congestion

According to Wikipedia, Traffic congestion is a condition in transport that is characterized by slower speed, longer trip times, and increased vehicular queueing. Traffic congestion on urban road networks has increased substantially since 1950s (Caves 2004). When traffic demand is great enough that the interaction between vehicles slows the speed of the traffic stream, this results in some congestion as shown in figure 2.1a below.

However, it has been argued that there is no single widely accepted definition of traffic congestion. The reason for this is associated with operational and user perspectives. The Joint Transport Research Centre (2007) of the Organization for Economic Cooperation and Development (OECD) and the European Conference of Ministers of Transport (ECMT) has provided the following definitions of traffic congestion to reflect the different broad perspectives:

- Congestion is a situation in which demand for road space exceeds supply.
- Congestion is the impedance vehicles impose on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches capacity.
- Congestion is essentially a relative phenomenon that is linked to the difference between the roadway system performance that users expect and how the system actually performs.

Just as the definitions of traffic congestion are broad so are the causes. There are many causes of traffic congestion and these differ from place to place, it is sometimes the result of urban development, housing, employment, cultural policies which cause people to live and work relative e to one another in close proximity (ECMT, 2007).

Figure 2.1a: Highly congested Intersection (Source: Destination tips, 2018)

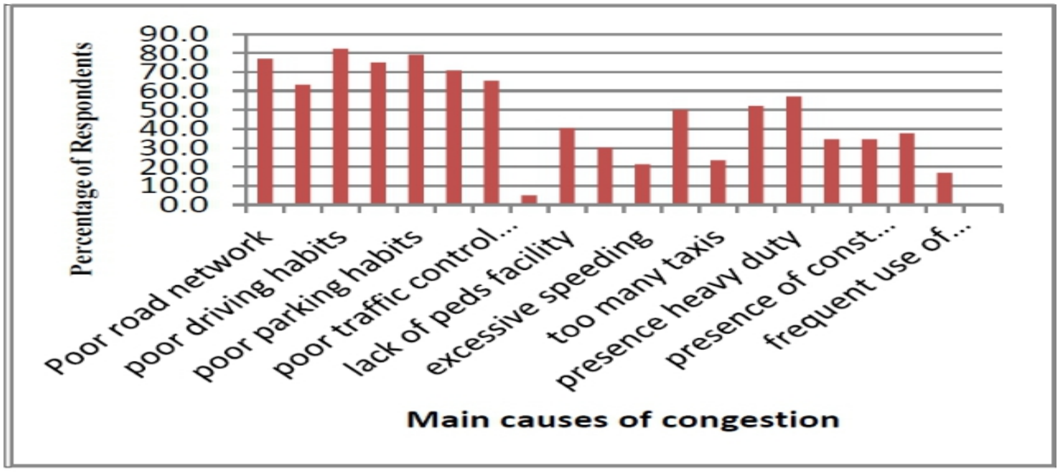


Figure 2.1b: Causes of traffic congestion (source: IJET, 2012)

A research work carried out by Joseph and Anderson (2012) showed that poor driving habits are the most significant cause of traffic congestion in Nigerian urban cities. Other major causes of traffic congestion they cited include: poor parking habits, poor road network, inadequate road capacity, lack of parking, poor drainage, presence of heavy vehicles, poorly designed junctions and roundabouts, lack of efficient mass transport system and poor traffic control/ management.

Figure 2.1b shows the summary of a survey carried out to determine the main causes of traffic congestion in a certain city in Nigeria.

2.2 Intelligent Traffic Control Systems

Intelligent traffic control system is defined as the application of advanced sensors, computer electronics and telecommunication technologies and management strategies in an integrated way to improve the safety and efficiency of the transportation system (Cai *et al.*, 2013). According to Vanajakshi (2010), the major goal of intelligent transportation systems is to evaluate, develop, analyze and integrate the sensors, information communication technologies, and concept to make efficient traffic flow to improve environmental quality, save energy, conserve time as well as enhance the comfort of drivers, pedestrian and other traffic users.

2.3 Backtracking

Backtracking is a general algorithm for finding all (or some) solutions to some computational problems, notably constraint satisfaction problems that incrementally builds candidates to the solutions, and abandons a candidate (“backtracks”) as soon as it determines that the candidate cannot possibly be completed to a valid solution (Gurari and Eitan, 1999). The term "backtrack" was coined by American mathematician D. H. Lehmer in the 1950s (Rossi *et al.*, 2006). The pioneer string-processing language SNOBOL (1962) may have been the first to provide a built-in general backtracking facility.

Backtracking is an algorithmic-technique for solving problems recursively by trying to build a solution incrementally, one piece at a time, removing those solutions that fail to satisfy the constraints of the problem at any point of time (by time, here, is referred to the time elapsed till reaching any level of the search tree). A typical backtracking state tree with all the solutions is shown in figure 2.8 below.

Basically, there are three types of problems in backtracking which include:

- Decision Problem – In this category, we search for a feasible solution.
- Optimization Problem – In this category, we search for the best solution.
- Enumeration Problem – In this category, we find all feasible solutions.

Backtracking can be applied only for problems which admit the concept of a "partial candidate solution" and a relatively quick test of whether it can possibly be completed to a valid solution. It is useless, for example, for locating a given value in an unordered table. When it is applicable, however, backtracking is often much faster than brute force enumeration of all complete candidates, since it can eliminate many candidates with a single test.

Backtracking is an important tool for solving constraint satisfaction problems, such as crosswords, verbal arithmetic, Sudoku, and many other puzzles (Gurari, 1999). It is often the most convenient technique for parsing, for the knapsack problem and other combinational optimization problems (Biere, 2009). It is also the basis of the so-called logic programming languages such as Icon, Planner and Prolog.

2.3.1 A Sample Standard Backtracking Problem: N-Queen Problem

The N-Queen is the problem of placing N chess queens on an N×N chessboard so that no two queens attack each other. For example, the figure 2.10 below is a solution for 4 – Queen Problem.

The expected output is a binary matrix which has 1s for the blocks where queens are placed. For example, the output matrix for the above 4 queen solution is shown below:

{ 0, 1, 0, 0}
{ 0, 0, 0, 1}
{ 1, 0, 0, 0}
{ 0, 0, 1, 0}

The algorithm for the Backtracking problem

The idea is to place queens one by one in different columns, starting from the leftmost column. When we place a queen in a column, we check for clashes with already placed queens. In the current column, if we find a row for which there is no clash, we mark this row and column as part of the solution. If we do not find such a row due to clashes then we backtrack and return false.

1) Start in the leftmost column
2) If all queens are placed return true
3) Try all rows in the current column. Do following for every tried row.
    (a) If the queen can be placed safely in this row then mark this [row, column] as part of the solution and recursively check if placing queen here leads to a solution.
    (b) If placing the queen in [row, column] leads to a solution then return true.
    (c) If placing queen doesn't lead to a solution then unmark this [row, column] (Backtrack) and go to step (a) to try other rows.
4) If all rows have been tried and nothing worked, return false to trigger backtracking.

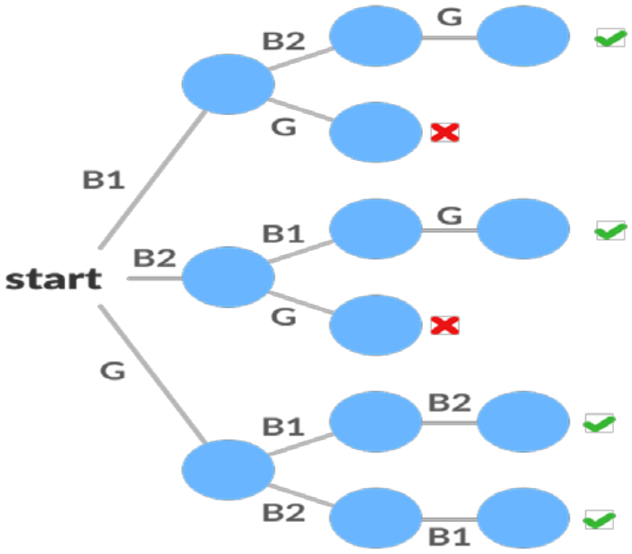


Figure 2.2: Backtracking state tree with all the solutions (source:https://www.programiz.com/dsa/backtracking-algorithm)

2.4 Historical Development of Traffic Control Systems

Road traffic control systems collect and analyze driving information of vehicles in an area, perform an optimal traffic signal control in accordance with the constantly changing road traffic situation, and provide useful road information to road users based on the data collected.

A number of studies have been conducted in Nigeria and elsewhere concerning traffic control systems. Research efforts in traffic engineering studies have yielded the queue traffic light model in which vehicles arrive at an intersection controlled by a traffic light and form a queue. Several research efforts developed different techniques tailored towards the evaluation of the lengths of the queue in each lane on street width and the number of vehicles that are expected at a given time of day. The efficiency of the traffic light in the queue model however, is affected by the occurrence of unexpected events such as the break-down of a vehicle or road traffic accidents thereby causing disruption to the flow of vehicles (Osigwe *et al.*, 2011).

Fathy *et al.,* (1995) proposed an algorithm based on the queue model. The algorithm consisted of motion detection and vehicle detection operations, both of which were based on extracting the edges of the scene to reduce the effects of variations in lighting conditions.

The first automated system for controlling traffic signals was developed by Leonard Casciato and Josef Kates and was first used in Toronto in 1954 (Engelmann, 1996). In 1996, Tan *et al* described a fuzzy logic controller for a single junction that should mimic human intelligence. The order of states was predetermined, but the controller was able to skip a state if there was no traffic in a certain direction. The amount of arriving and waiting vehicles were quantified into fuzzy variables, like many, medium and none. In experiments the fuzzy logic controller showed to be more flexible than fixed controllers and vehicle actuated controllers, allowing traffic to flow more smoothly, and reducing waiting time. A disadvantage of the controller was its dependence on the preset quantification values for the fuzzy variables which indicated that the system could fail if the total amount of traffic varies. Furthermore, the system was only tested on a single junction (Tan *et al.*, 1996).

A decentralized control model was described by Jin and Ozguner (1999). This model was a combination of multi-destination routing and real time traffic light control based on a concept of cost-to-go to different destinations.

GiYoung *et al.,* (2001) believed that electro-sensitive traffic lights had better efficiency than fixed preset traffic signal cycles because they were able to extend or shorten the signal cycle when the number of vehicles increases or decreases suddenly. Their work was centered on creating an optimal traffic signal using fuzzy control. Fuzzy membership function values between 0 and 1 were used to estimate the uncertain length of a vehicle, vehicle speed and width of a road and different kinds of conditions such as car type, speed, delay in starting time and the volume of cars in traffic were stored.

Also, Findler and Stapp (2002) described a network of roads connected by traffic light based expert systems. For each traffic light controller, the set of rules were optimized by analyzing how often each rule fires, and the success it had. The system was said to be able to learn new rules. Research have shown that their system has the ability to improve performance, but they had to make some simplifying assumptions to avoid too much computation.

Huang and Miller (2004) established a believe that electronic traffic signal is expected to augment the traditional traffic light system in future intelligent transportation environments because it has the advantage of being easily visible to machines. Their work presented a basic electronic traffic signaling protocol framework and two of its derivatives, a reliable protocol for intersection traffic signals and one for stop sign signals. These protocols enabled recipient vehicles to robustly differentiate the signal's designated directions despite of potential threats (confusions) caused by reflections. They also demonstrated how to use one of the protocols to construct a sample application: a red- light alert system and also raised the issue of potential inconsistency threats caused by the uncertainty of location system being used and discuss means to handle them.

Chattaraj *et al.,* (2008) proposed a novel architecture for creating Intelligent Systems for controlling road traffic. Their system was based on the principle of the use of Radio Frequency Identification (RFID) tracking of vehicles. This architecture can be used in places where RFID tagging of vehicles is compulsory and the efficiency of the system lied in the fact that it operated traffic signals based on the current situation of vehicular volume in different directions of a road crossing and not on pre-assigned times. Also, a framework for a dynamic and automatic traffic light control expert system was proposed by Wen (2008). The model adopted inter-arrival time and inter-departure time to simulate the arrival and leaving number of cars on roads. Knowledge base system and rules were used by the model and RFID were deployed to collect road traffic data. This model was able to make decisions that were required to control traffic at intersections depending on the traffic light data collected by the RFID reader.

Abdul Kareem and Jantan (2011) designed an intelligent traffic light monitoring system using an adaptive associative memory. The research was motivated by the need to reduce the unnecessary long waiting times for vehicles at regular traffic lights in urban area with 'fixed cycle' protocol. To improve the traffic light configuration, the paper proposed monitoring system, which will be able to determine three street cases (empty street case, normal street case and crowded street case) by using small associative memory. The experiments presented promising results when the proposed approach was applied by using a program to monitor one intersection in Penang Island in Malaysia.

Zade and Dandekar (2011) developed an Intelligent Traffic Signal Controller using FPGA controller based on Neuro-Fuzzy system capable of taking decision to reduce delays at intersection. The designing part of the controller into VHDL program eliminated the shortcomings of other custom facilities and conventional controller designs available today.

Furthermore, Ganiyu *et al.*, (2011) focused on the use of Timed Coloured Petri Nets (TCPN) to model a multi-phase traffic light controlled cross-type intersection using cross-type junction of fixed signal timing plan located in Federal Capital Territory, Abuja, Nigeria, as a case study.

Mohit *et al.*, (2012) employed a method proposed to reduce heavy traffic congestion on the road by using PLC based traffic diversion system; employing the working of weight sensors whose output were fed to a Programmable Logic Controller (PLC) to control the traffic diversion. Rotake and Karmore (2012) proposed an evolutionary approach to estimate the traffic volumes of road networks.

Hashim *et al.*, (2013) designed a traffic system that was capable of receiving signal from emergency vehicles based on radio frequency (RF) transmission and used the Programmable Integrated Circuit (PIC) 16F877A microcontroller to change the sequence back to the normal sequence before the emergency mode was triggered. Ashish *et al.*, (2013) proposed the optimization of the traffic light controller in a city using ultrasonic sensor and microcontroller with fault detection technique. Their proposal included an idea for a dynamic and automatic traffic light control expert system combined with a simulation mode.

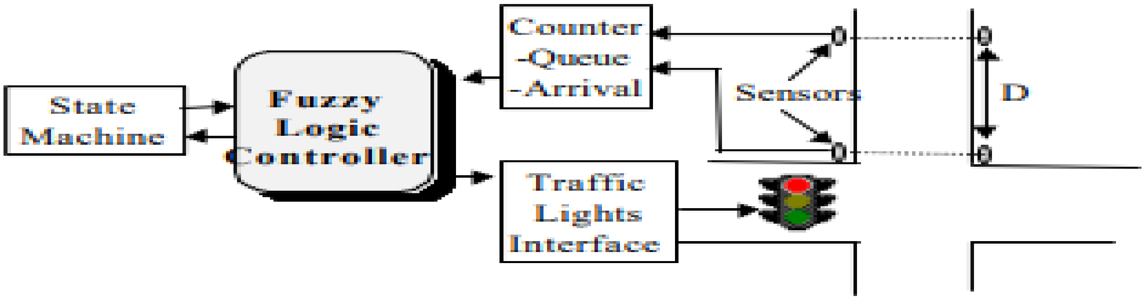


Figure 2.3: A general structure of the fuzzy traffic controller (source: Milan et al, 2015)

Sharma *et al.*, (2013) proposed an RFID traffic control system that was capable of solving the problems that usually arise with standard traffic control systems, especially those related to image processing and beam interruption techniques. This RFID technique was employed with a multivehicle, multilane, multi road junction area. It provided an efficient time management scheme, in which a dynamic time schedule was worked out in real time for the passage of each traffic column. The real time operation of the system emulated the judgment of a traffic policeman on duty. The number of vehicles in each column and the routing were proprieties, upon which the calculations and the judgments were based. A prevailing shortcoming of this technique was/ is the problem of tag collision. Tag collision occurs when numerous tags are present in a confined area. The RFID tag energizes multiple tags simultaneously, all of which reflects their signals back to their readers. This results in tag collision, and the RFID reader fails to differentiate between incoming data. RFID reader collision results when the coverage area managed by one RFID reader overlaps with the coverage area of another reader. This causes signal interference and multiple reads of the same tag.

Also Ganiyu *et al.,* (2014) designed and implemented a traffic light system for road intersection control; using image processing technique. Kavya *et al.,* (2014) proposed the design of an intelligent traffic control system and noted that by continuously sensing and adjusting the timing of traffic lights according to the actual traffic load, the traffic congestion problem could be solved. Ramteke *et al.,* (2014) designed, simulated and synthesized a simple, suitable and reliable VLSI fuzzy processor for controlling the traffic lights.

Sagar and Lokhande (2017) developed an intelligent traffic control system to pass emergency vehicles smoothly in their work titled “Implementing Intelligent Traffic Control System for Congestion control, Ambulance Clearance and Stolen vehicle detection”. In their work, each individual vehicle was equipped with special radio frequency identification (RFID) tag (placed at a strategic location).Their system was able to count number of vehicles that passes on a particular path during a specified duration. In addition, when an ambulance is approaching the junction, it will communicate to the traffic controller in the junction to turn ON the green light.

Lee *et al.,* (2019) studied the use of fuzzy logic in controlling multiple junctions. Comparisons with fixed fuzzy-logic traffic light controllers indicated that this enhancement can lead to larger traffic flow under very crowded traffic conditions.

It could be seen from various studies that traffic system management is critical and in view of this, there is need for the design of a simple and cost effective intelligent traffic control system devoid of complexities but capable of recursively tracking the lanes of the roads as well as take advantage of the appropriate technologies to create “more intelligent” roads. This is what this work seeks to achieve.

2.5 Current Situation of Traffic Control Around the world

2.5.1 Traffic Warden

Traffic wardens are responsible for making sure that traffic and parking and regulations are observed. They monitor the use of parking meters, controlled parking zones and one-way systems, and check for infringements of waiting restrictions and restrictions on the loading and unloading of goods. A typical traffic warden is shown in Figure 2.4 below:

Figure 2.4: A Traffic Warden (source: https://www.meeteverydaypeople.com.ng/2018/01.)

2.5.2 Fixed – cycle Traffic Light System

The system only uses a fixed – cycle time in switching the traffic lights at each junction, which does not consider the real –time condition of the corresponding intersection, such as the number of vehicles and pedestrians at the junction. And it does not take of their needs, especially the waiting time and the pass –

through time. This type of control system is widely used around the world. It is one of the oldest methods of traffic control system. A typical fixed – cycle traffic light system is shown is Figure 2.5.

2.5.3 Area Traffic Control System

Area traffic control (ATC) system has been applied in Hong Kong since 1977, as the first computerized adaptive traffic control system (Lee *et al.*, 2014). The system deployed two different adaptive traffic control technologies, namely, Split Cycle Offset Optimization Technique (SCOOT) and Sydney Coordinated Adaptive Traffic System (SCATS) in which traffic signal was controlled by detecting the number of vehicles and calculating their speed when they passed through the detector loops set on vehicles lanes (Stevanovic et al, 2009). The data are then transferred to the control server to adjust the parameters to the adaptive control algorithm that result to an optimal duration of green lights to release the vehicles, thus reducing traffic congestion. However, the system focused on management of the vehicles passing through the junction, but sacrifices the benefits of pedestrians that shortened the crossing time for pedestrians which increased the risk of people trying to cross the road when the red light is on the pedestrians. However, it was established that SCOOT and SCATS cannot provide rapid responses to traffic fluctuations at various intersections. A typical Area traffic control system is shown in Figure 2.6.

Figure 2.5: Fixed Cycle Traffic Light System (source: https://www.howimportant.com)

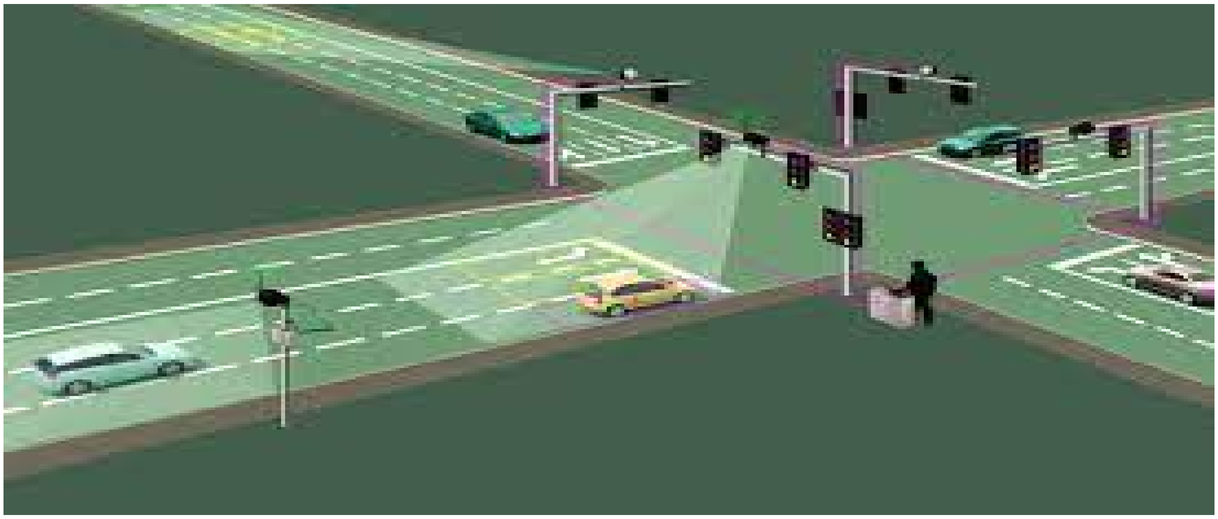


Figure 2.6: Area traffic control system (source: https://www.trafiksol.com/urban-traffic-management-system)

2.5.4 Smart Traffic Light System

Smart traffic lights are vehicle traffic control systems that combine traditional traffic lights with an array of sensors and artificial intelligence to intelligently route vehicle and pedestrian traffic. The signals communicate with each other and adapt to changing traffic conditions to reduce the amount of time that cars spend idling. Using fiber optic video receivers similar to those already employed in dynamic control systems, the new technology monitors vehicle numbers and makes changes in real time to avoid congestion wherever possible.

Initial results from the pilot study are encouraging: the amount of time that motorists spent idling at lights was reduced by 40% and travel times across the city were reduced by 26%.

Smart traffic light system set up for Tai Tam Road (Dam section) was developed and implemented by Cheng and his research team at The Chinese University of Hong Kong in 2018. The type of vehicle will be detected by eight sets of cameras installed at the street lamps on Tai Tam Road. It then calculates the green signal time, according to the data received by all cameras analyzing the traffic queue of each side of the dam and the presence of heavy vehicles like a double – decker bus and fire engine in parallel. On the Tai tam Road (dam section), there is a specific condition, and fewer traffic situations occur due to lack of traffic control systems to perform the signal timing optimization at junctions in urban districts, especially in Central, Mong Kok and Tsim Sha Tsui in Hong Kong. Based on the available open data, such as street-facing surveillance cameras and navigation applications like the street view function in Google Maps, real-time detecting the number of vehicles and density of pedestrians in waiting or crossing the road at a specific intersection can be realized. This information describes the real-time traffic conditions of road intersections more clearly, hence a useful resource to drive the development of intelligent traffic control systems. A typical example is shown in Figure 2.7 below:

Figure 2.7: Smart Traffic Light System (Source: https://medium.com/civic-analytics/smart-traffic-lights)

2.6 Review of Current Technologies

2.6.1 Object Detection of Machine Learning Technology

Cheng (2019) applied object detection to classify the type of vehicle when the vehicle passes through the checkpoints in Tai Tam Road. Object detection is applicable in determining the type of object and also locating its position by quoting a bounding box around it. Furthermore, it also presents the information of the detected object in an image once classified (Pathak *et al.*, 2018). Object detection therefore is well in use for detecting vehicles and pedestrians in the real scenario by setting up cameras at the intersections.

2.6.2 Simulation

A simulation is an imitation of a model based on a system in reality. A simulation model can change different parameters, then perform testing for a system that is costly or difficult to be constructed. A simulation model can be used to investigate different states (Maria, 1997).

A simulation environment can be built to show the scenario by using the new traffic light application, comparing with the current FCTL system. Moreover, it can simulate the operations in different traffic conditions by using the new application.

2.7 Review of Existing Solutions

Smith *et al.,* (2013) proposed a scalable urban traffic control system that monitors the number of vehicles in real-time by installing detectors at intersection by scanning the sensors installed in vehicles. The traffic data gathered are transferred to the traffic control to set up a scheduled scheme to apply to the intersections. Chavan *et al.,* (2009) proposed an intelligent traffic light controller using an embedded system. The driver receives route suggestions as a reference to the destination by processing using, which connecting with analyzing the traffic flow data came from sensors set of intersections. Nie (2018) developed an intelligent traffic lights system using object detection to find out the number of vehicles at an intersection by cameras. Then fine-tune the traffic light switching by the results of the traffic density. Although those systems performed well, they gave up other vital elements like the precision that an incorrect vehicle queue was detected by a container truck. Also, they may be costly, especially the scalable urban traffic control system (Smith *et al*, 2013), that needs to install an extra component to vehicles which means the system cannot be operated if vehicles pass through the road without installing sensors.

Emami *et al.,* (2018) suggested that machine learning technology is a way to solve the problem as a result of the old-styled applications not being able to satisfy the requirements in modern cities. In using deep learning, more precise information such as the type and speed of the vehicle were realized. Hawi *et al.,* (2015) introduced fuzzy expert systems and established that wireless sensor networks proposed by Yousef *et al.,* (2010) assist to optimized traffic in intersections when the traffic data are shared between the intersections. While fuzzy logic and wireless technologies become famous in solving this type of issue, the fundamental problem has not been resolved. That is, sensors are required to maintain the detection; hence much more costs will be required based on the well-developed traffic network such as Hong Kong. Furthermore, to conduct the data sharing between intersections and massive power to support the data exchange is also needed. While performing site testing may not be permitted in Hong Kong, simulation can perform different conditions virtually that will not affect the real traffic, especially in high traffic flow districts. Simulation of Urban Mobility (SUMO) simulator has been applied to generate the actual scenario in Mong Kok by Behrisch *et al.,* (2011). SUMO created the road map according to the online maps. Then, the traffic flow was made and imported to the simulator. Although SUMO can generate traffic flow very well, it cannot fulfill the present day traffic needs. The traffic map cannot be modified once created so that there is a barrier to making a change to the road according to rapid constructions made or new facilities being implemented.

In summary, sensors are frequently used in different solutions in detecting traffic conditions. However, limited data gathering and maintenance of these devices has become complicated (Nie, 2018). In improving traffic control, object detection technology becomes more flexible and more practicable.

3, METHODOLOGY

3.1 Design for Density Based Traffic Light Control System

The approach to this design was based on the design and implementation of its input subsystem, control unit (control program) and output subsystem. The input subsystem was made of sensors, programmed and implemented using some already existing principles to achieve optimum performance. The control unit was realized by a microcontroller-based control program, which will interpret the input and qualify it to produce a desired output.

3.2 Principle of Operation

The block diagram of the entire system as presented in Figure 3.1 shows the major components of the system. These include:

- Mains Supply
- DC Power Supply
- Sensors Arrays
- Controller
- Traffic Lights

The block diagram was drawn so as to give a vivid explanation of how the system will work at a glance, thus; the main supply provides a 230VAC power which is converted to 5VDC (VDD) by the DC power supply that is used to power the sensor arrays, the controller, and traffic lights. The sensors will provide input to the controller which then will perform some logical operations to power the traffic lights as output used for controlling traffic at road intersections.

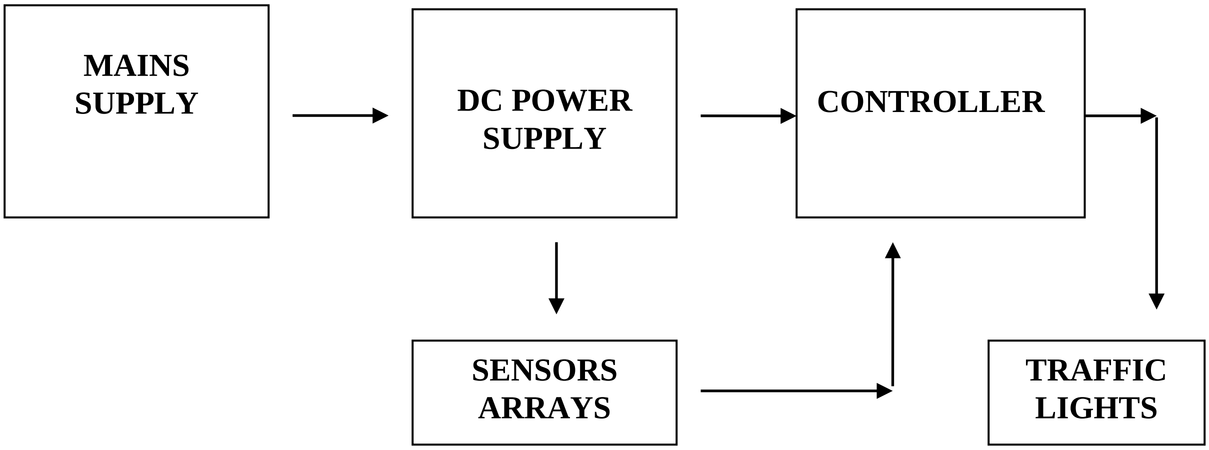


Figure 3.1: Block schematic diagram of the Intelligent Traffic Control System

3.3 Choice of the Major Components used

3.3.1 Choice of Sensors for Sensors Arrays

In choosing the sensors, the following features were taken into consideration: accuracy, range, calibration, resolution and affordability. Although the LDR sensors are usually disturbed by noise in the surrounding such as radiations, ambient light etc., they were used for this design because they are cheap and readily available in the market and are easy to interface. A typical LDR sensor is shown in Figure 3.2 below.

3.3.2 Choice of Microcontroller and Peripherals

Although the microcontroller Arduino mega has a few disadvantages relating to its possession of a single accumulator, but it was employed in the implementation because of the following features:

- Most effective and efficient microcontroller for use to accomplish the objective of the design;
- Low cost, low percentage of faulty rate and very consistent;
- More pins available for use in implementation of the design features;
- Very fast because of its RISC architecture;
- Low power consumption and ease of programming;
- Ease of interfacing of an analog device without any extra circuitry.

A picture of a typical Arduino mega 2560 circuit board is shown in figure 3.3 below.

Figure 3.2: LDR sensors

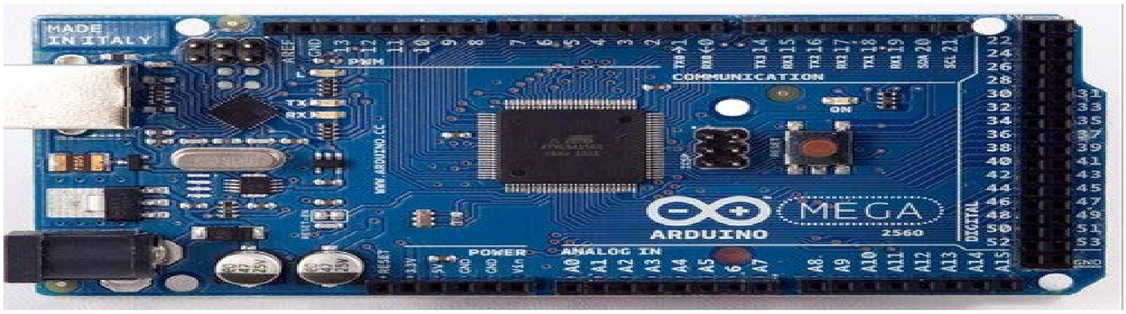


Figure 3.3: Arduino mega 2560 circuit board

3.3.3 Choice of Traffic Light Indicators

Just like the conventional traffic light indicator, this design controls traffic using three light emitting diodes, 'GREEN', 'YELLOW' and 'RED', each having their usual meaning of 'GO', 'READY' and 'STOP' respectively. They are controlled by the control buses of the microcontroller depending on the logical decisions taken by the controller to control the lanes of traffic according to their densities. Figure 3.4a and figure 3.4b shows the pictures of LEDS and traffic light indicators respectively.

3.4 Infrared Sensors Arrangement and Implementation

The design was focused on sensing the traffic level on each of the lanes of the road depending on the density of each lane using Light Dependent Resistors (LDR) sensors. The arrangement of the sensors on the road layout was positioned to perform this function.

For each lane of traffic to be controlled, four sensor arrays was deployed and arranged in an array of four, two transmitters and two receivers.

3.5 Mode of Operation

At the time when the traffic control will commence operation, the states of all the sensor arrays on each lane of traffic was read and given as input to the microcontroller for logical operations. The system was then assigned serial numbers to each lane based on their density, where the lane with the most density is will be assigned lane one (1). Accordingly, the system will set the ready flag for lane one where the YELLOW light shows; in preparation for the passing of traffic in that lane and will delay for a certain time before giving the go signal with the GREEN light. The flow diagram for the mode of operation of the whole system is shown in Figure 3.6 while Figure 3.8 indicates the circuit diagram of the intelligent traffic control system. The block diagram of the mode of operation of the whole system is shown in Figure 3.7.

Figure 3.4a: LEDs

Figure 3.4b: Traffic light indicators

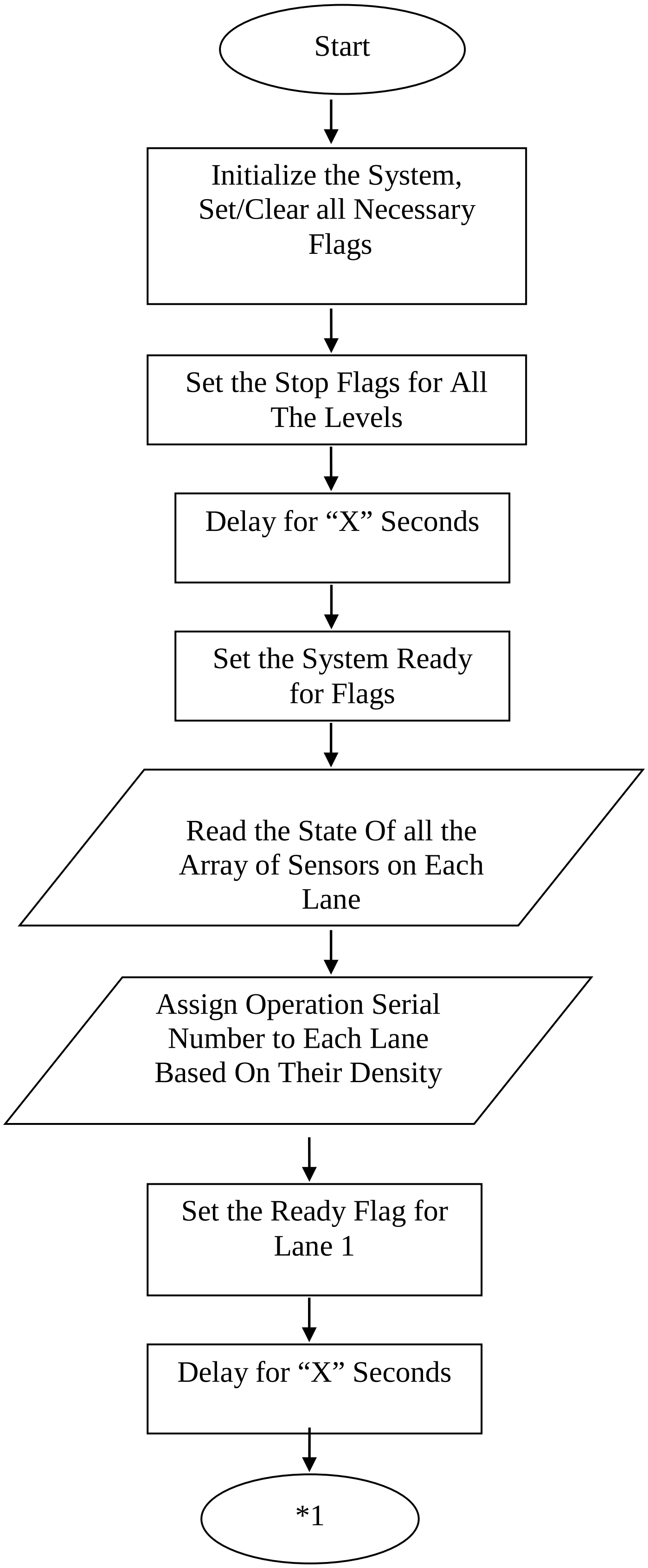

Start
Initialize the System, Set/Clear all Necessary Flags
Set the Stop Flags for All The Levels
Delay for “X” Seconds
Set the System Ready for Flags
Read the State Of all the Array of Sensors on Each Lane
Assign Operation Serial Number to Each Lane Based On Their Density
Set the Ready Flag for Lane 1
Delay for “X” Seconds
*1

Figure 3.5: Diagram of flowchart showing the arrangement of infrared sensors of the system

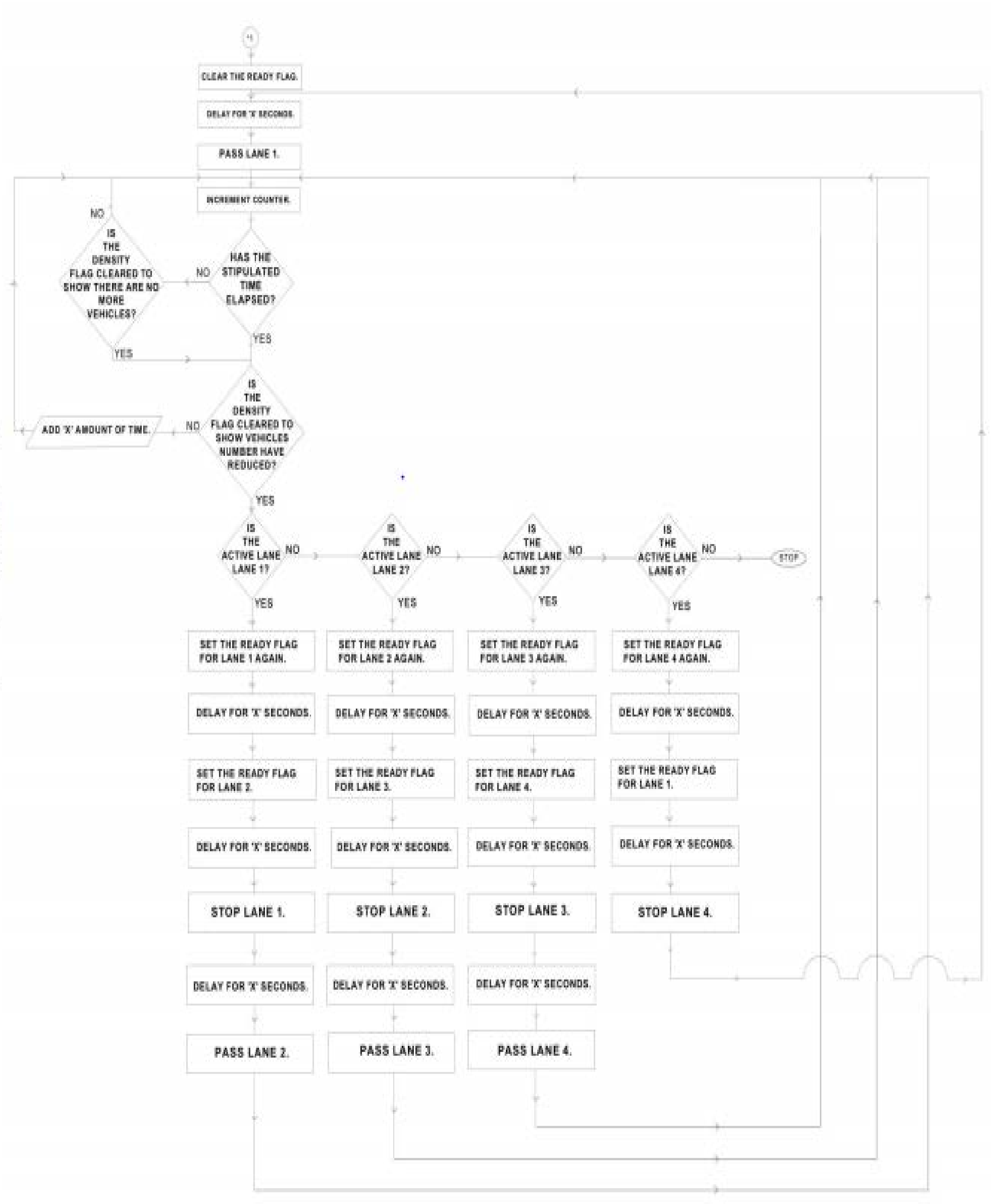


Figure 3.6: Block Diagram of the whole system

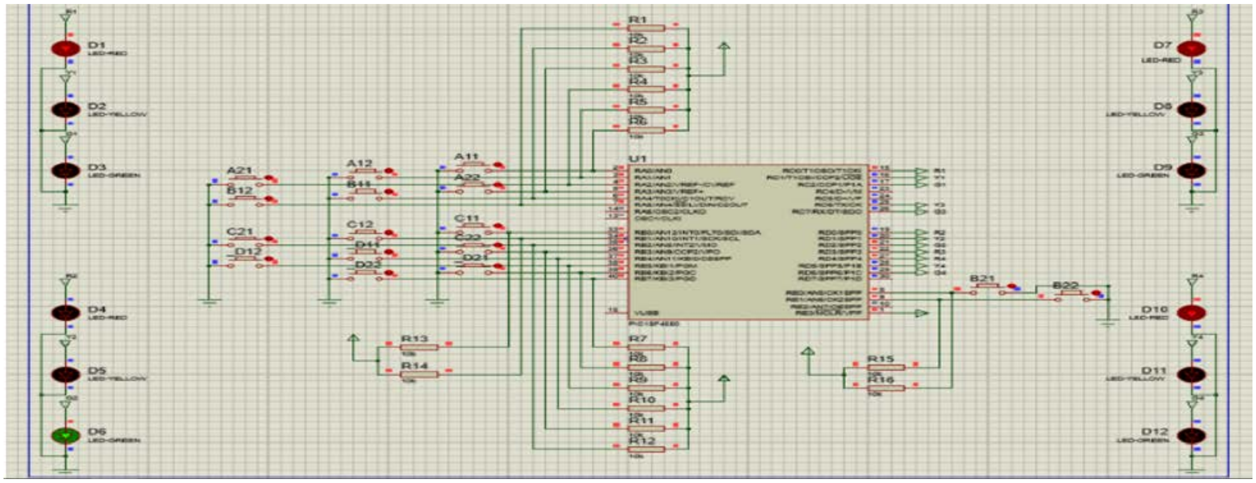


Figure 3.7: Circuit diagram of the intelligent traffic control system

Going further, to implement the primary loop of the flow chart; the system will increment the counter where the amount of time allotted for lane one will be accounted for; and it will take a decision when the go time for lane one has elapsed. Conversely, the system will take a decision on the density of traffic on lane one by checking when the density flag will be cleared; If no, the system will increment the counter again. After the density flag would've been cleared and time has elapsed, the system will make a decision further to verify that the density flag has been cleared, if not, additional time will be added and the primary loop will be performed again. When the density flag for lane one will be cleared, it will make a decision by checking to see if either lane one or any of the other three lanes are active, if not, the program will stop. When lane one is the active lane, the ready flag for that lane will be set again and the YELLOW light will show in preparation to stop traffic on that lane while simultaneously setting the ready flag for lane two. Once lane one has been stopped, the YELLOW light at lane two will show indicating readiness and eventually the lane will be passed and the primary loop of the system will be performed again. This process will be repeated for all the other lanes depending on which one is the active lane. All these operations will be performed by the logic operations carried out by the microcontroller through series of codes embedded in the controller.

Figure 3.11 below shows the logic flow of the traffic control system. The logic was be made up of twelve AND gates which was a representation of the sensors at the different lanes of the traffic light. An AND gate is a logic circuit having two or more inputs and one output. The output of an AND gate is HIGH only when all of its inputs are in the HIGH state. In all other cases, the output is LOW. When interpreted for a positive logic system, this means that the output of the AND gate is a logic ‘1’ only when all of its inputs are in logic ‘1’ state. In all other cases, the output is logic ‘0’. The logic gate will make comparison from the different sensors and will then give the output to the microcontroller which will make the final decision.

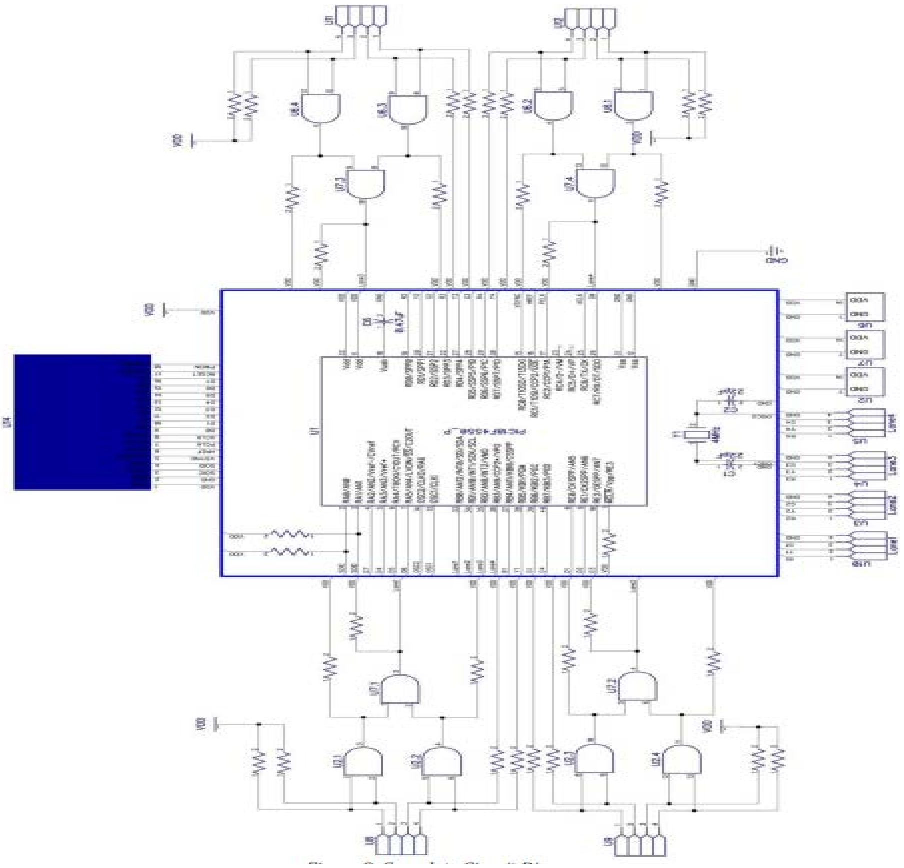


Figure 3.8: Logic flow of the traffic control system

4. RESULTS AND DISCUSSIONS

4.1 System Implementation and Experiment Results

In this section, the design and implementation details of the intelligent traffic control system with backtracking are discussed. The integration of the traffic signal controller is introduced, and the integration test is presented. Unit and functional test of different communication protocols, and demonstration of the field experiment on numbers of vehicle are presented in this section.

4.2 System Implementation

Intelligent traffic control system with backtracking was implemented using an embedded microcontroller (Arduino mega), which connects the sensors (LDR sensors) and the LEDs. The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The LDR are connected to the microcontroller with a pulldown resistor through an analog to digital converter and the LEDs through the analog to digital converter (ADC).

4.3 Analog to digital converter (ADC).

Analogue to Digital Converter, or ADC, is a data converter which allows digital circuits to interface with the real world by encoding an analogue signal into a binary code. ADC, allow micro-processor-controlled circuits such as Arduinos, Raspberry Pi, and other such digital logic circuits to communicate with the real world. In the real world, analogue signals have continuously changing values which come from various sources and sensors which can measure sound, light, temperature or movement, and many digital systems interact with their environment by measuring the analogue signals from such transducers.

The microcontroller receives data from the LDR which is then used for the algorithm and the result of the algorithm is send as an output to the LEDs

4.4 Testing

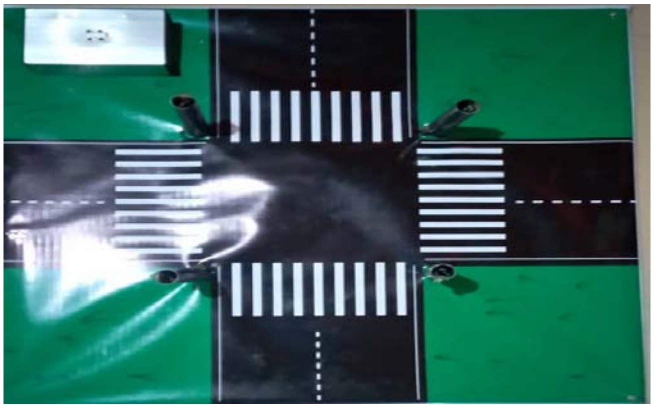
The testing of the project was carried out in an open field where there was little or no shades. The breadboard experiment was developed using multi-LEDs in which part of the LEDs was used as signal indicator. The project is powered by a 9v battery. After powering the project, the project goes into a boot up stage which is for 5 seconds and then the program initializes. At this point the sensor begins to send data of each lane to the microcontroller. Plate 4.1 below shows the system during the testing process.

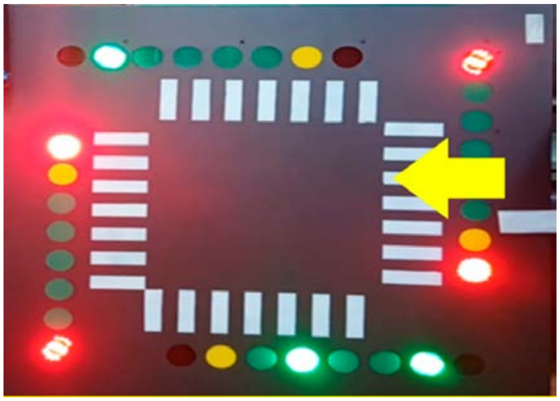
4.5 Results

The design was able to provide the quickest possible clearance to vehicular traffic in all directions at a junction, as well as monitor, regulate and pave way for vehicles on congested lanes while keeping track of the other lanes.

4.6 Discussions

The designed intelligent traffic control system has the ability to learn from the environment and sense the traffic conditions at all lanes in an intersection at real time. While in operation, it takes note of the traffic density on each of the lanes through the LDR sensors and sends signals to the microcontroller which then activates the LEDs accordingly. While the flow of traffic is ongoing, and any vehicle is spotted in any of the junction, the LDR sensor on that lane sends a signal to the microcontroller, which in turn triggers a “pass signal” by turning ON the green LED on that lane while also turning ON the red LEDs on the other lanes.





Also, when there is congestion, the system automatically pass the densest lane while keeping track of the less congested lanes by measuring the traffic condition on the other lanes to make decision on which lane pass next.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In this work, a backtracking model smart traffic control system for the infrastructure in the smart city is developed, which can be widely applied for the intelligent transportation system in smart city applications. The major components in the proposed intelligent traffic control system with backtracking include Arduino mega microcontroller and LDR sensors.

The Arduino mega controller is the core of this work, where we discussed in detail the system architecture, middleware, peripheral hardware modules, and control algorithms. The intelligent traffic control system with backtracking designed follows the urban traffic control protocol so that it is compatible with a traditional traffic signal controller and can be fast and cost-effectively deployed. A new traffic signal scheme is specially designed for the emergency vehicle signal preemption scenario; it can inform all the drivers near the intersection when emergency vehicle is approaching, smoothing the traffic flow and enhancing the safety without extra hardware costs.

5.2 Recommendations

In this research work, it is assumed that queue lengths can be observed accurately, and there are no pedestrians. To apply the proposed intelligent traffic control system model in the real world, it is necessary to conduct future studies that take pedestrians into account. Also, an accurate and reliable queue detection method as well as a robust in-depth research into backtracking needs to be developed.

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