International Journal of Research in Mechanical and Materials Engineering

Journal homepage: http://mcmed.us/journal/ijrmme

MODELLING OF A FUZZY TRAFFIC LIGHT CONTROLLER

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Article Info

Received: 15/08/2014
Revised: 01/09/2014
Accepted: 11/09/2014

Key words: Traffic control, Fuzzy tool, Logic controller.

ABSTRACT

There is a need to cater for geometric increase in the number of road users on our road and in order to avert road congestion, accidents, and other possible effects; the need for research into traffic light controller becomes imperative. Operating traffic signals is inherently a difficult task with many conflicting objectives. This research designs and simulates a fuzzy traffic light control system using method that incorporates fuzzy logic to control the phase-splits of the traffic light at road intersections. MATLAB (fuzzy tool) software is used to simulate the effectiveness of fuzzy logic controller in controlling traffic conditions at intersections. The fuzzy traffic controller operates by determining whether to extend or terminate the current green phase, based on a set of fuzzy rules which consists of the IF … THEN rules, that are used for its decision. The fuzzy rules compare the traffic conditions with the current green phases and with the next candidates green phase.

INTRODUCTION

Over the years, movement of all living and non-living things is one major activities which is common and inevitable among men for their survival. This activity remains an essential and important aspect of every human life in our world today. The movement involves the use of the various forms of transportation including road, rail, and water transportation. Among these, road transportation is the earliest and unavoidable form of transportation. In the olden days, it involves the movement of people and goods through the use of some animals like cattle, donkey etc. and the use of various types of vehicles in our world today. As a result of the ever increasing population of most countries, there is also an increase in the number of vehicles and traffic demand on our road today and this has led to issues of traffic congestion, air pollution, sound pollution, weariness, stress time and energy wastage [1]. However, as modern technology is on the ever increasing side and with advancement in technology, different researches are being carried out in order to decrease and eliminate completely the long existing problems that are encountered in road transportation and to improve the reliability and efficiency of the road network so as to yield both economic and environmental benefits. The various attempts that have been made to improve the traffic flow were idealizations of the roads, widening of the roads at approaches to the intersection, banning of various turning movements erecting signals at various intersections introducing round about at the road intersection and introducing human traffic warders which are being replaced by the conventional traffic light control. Traffic light is the most familiar important and effective method of traffic control which is generally installed to ensure safely, decrease the average time of proceeding through the intersection, improve quality of service, quality of traffic flow etc.

The conventional traffic light control is a traffic light signal control that is based on preset cycle time and precise models in which the light signal changes at constant cycle time in order to control the traffic situation. Due to the fixed cycle time, the conventional traffic light control do not consider the waiting time on signals of different intersections and also do not carry out any analysis of traffic situation and as such are incapable of responding to the transportation demand volumes and decrease in density. As such they fail to deal effectively with the complex and time varying traffic situations [2]. In view of this, new methods like genetic algorithms neural network and fuzzy control are coming into the field of adaptive traffic signal control to replace the earlier conventional traffic control. These new algorithms are continually improving the safety and efficiency by reducing the waiting delay of vehicles on signals and this increases the tempo of travel and thus makes signals more effective and traffic flow smooth. The fuzzy control which has proved to be superior and good manager in the traffic signal control in any situation combines preset cycle time with proximity sensors that have the ability to take decision even with incomplete information and also activate a change in the cycle time or the light. This research focuses on the design and implementation of fuzzy traffic light controller as an attempt to provide lasting solution to problems caused by the ever increasing number of road users by controlling traffic flow according to the density of vehicle on road. The research aims to design and simulate a fuzzy traffic light controller

LITERATURE REVIEW

Historical Background of Traffic Control Signal

The world's first traffic light came into being before the automobile was in use; and traffic consisted only of pedestrians, buggies, and wagons. Installed at an intersection in London in 1868, it was a revolving lantern with red and green signals. Red meant "stop" and green meant "caution." The lantern, illuminated by gas, was turned by means of a lever at its base so that the appropriate light faced traffic. On January 2, 1869, this crude traffic light exploded, injuring the policeman who was operating it. With the coming of automobiles, the situation got even worse. Police Officer William L. Potts of Detroit, Michigan, decided to do something about the problem. What he had in mind was figuring out a way to adapt railroad signals for street use. The railroads were already utilizing automatic controls. But railroad traffic traveled along parallel lines. Street traffic traveled at right angles. Potts used red, amber, and green railroad lights and about thirty-seven dollars' worth of wire and electrical controls to make the world's first 4-way three color traffic light. It was installed in 1920 on the corner of Woodward and Michigan Avenues in Detroit. Within a year, Detroit had installed a total of fifteen of the new automatic lights. At about the same time, Garrett Morgan of Cleveland, Ohio realized the need to control the flow of traffic. A gifted inventor and reportedly the first African American to own an automobile in Cleveland, Ohio, he invented the electric automatic traffic light which looked more like the semaphore signals seeing today at train crossings today. Many other researchers had obtained US Patents for Traffic Signals, some as early as 1918. But Morgan's Patent was purchased by General Electric Corporation and provided the protection they needed to begin building a monopoly on traffic light manufacture. However, the control of traffic is an unavoidable, integral and important part of modern society, and with an increasing population and increasing mobility, traffic jams are becoming more common sight, especially in and around large areas. This leads to significant economic damage and environmental pollution. As a result of this inadequacy, there are several ways and models for controlling traffic. Research has shown that such models yield realistic behavior [3].

Traditionally, the main performance measure for judging efficiency of traffic signal control systems has been the reduction of vehicles delay and stops [4]. Nowadays, the traffic signal design can be viewed through measures of performance of intersection operation criteria or desirable outcomes. Hence, a decrease in delay, number of stops ,fuel consumption, pollutant emissions, noise, vehicle operating costs and queue length as well as an increase in consideration for pedestrians, bicycle and public transport vehicles and also in safety are all desirable. Traffic control equipment has also followed technology development. At the very beginning, traffic control had been performed by electro-mechanical devices. Then semi-controller based controllers were introduced and nowadays, microprocessor-based controllers are used in traffic control systems. The development in the area of traffic control systems has led to the introduction of the use of new techniques, methods, devices etc.

Traffic Control System

Traffic control is the supervision of the movement of people, goods or vehicles to ensure efficiency and safety. A traffic light system is an electronic device that assigns right of way at an intersection or crossing or street crossing by means of displaying the standard red, yellow and green coloured indications. It also works in conjunction with pedestrian displays to assign pedestrian crossing right of way and also, to help vehicles and vessels to safely share the same roads, rails, waterways or air space. A traffic light, also known as traffic signal, stop light, stop-and-go lights, is a signaling device positioned at a road intersection, pedestrian crossing, or other location in order to indicate when it is safe to drive, ride, or walk using a universal color code (and a precise sequence, for that are colors blind). Nowadays, a red light meant traffic in all directions had to stop. A yellow light meant cross-town traffic would have to slow and a green light meant cross-town traffic would have to go or proceed.

Benefit of Traffic Light Controller

When properly used, traffic control signals are important devices for the control of vehicular in road. They assign the right-of-way to a choice of traffic movements and thereby deeply influence traffic flow. Traffic control signals that are properly designed, located, operated, and maintained will have one or more of the following advantages:

- Provide orderly movement of traffic
- Minimize completing movement

- Coordinated for continuous movement
- Provide driver confidence by assigning right way

Traffic Control Strategies

Traffic strategies; involve the various strategies, which are used to control the flow of traffic so as to enhance efficiency and coordination thereby minimizing the total time spent by all the vehicles in the network. Traffic control strategies also improved since the installation of the first traffic controller and these strategies can be classified [5]. The two most important strategies are (i) Fixed-Time (FT) strategies and (ii) Real-Time (RT) strategies

(i) Fixed-Time (FT) Strategy: This strategy uses a preset cycle time to change the lights. The control (signal plan) is calculated in advance using statistical data. In the timing plan of a fixed-time strategy, the red and green period (right of way), are set to predetermined intervals and remained unchanged until they are reset. Each phase of the signal lasts for a specific duration before the next phase occurs; this pattern repeats itself regardless of the traffic. Many older traffic light installations still use these but they are however quite disadvantageous when the signal timing for intersection would profit from being adapted to the dominant flows changing over the time of the day.

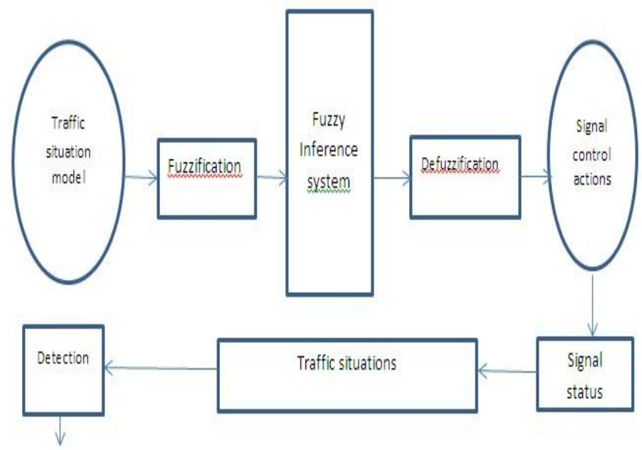
(ii) Real-Time (RT) Strategy: This strategy combines preset cycle time with proximity sensors, which can activate a change in the cycle time or the light. The real-time data about traffic processes are used to determine control or its modification. The proximity sensors in this strategy, are used to detect the presence of traffic waiting at the light, and thus can avoid giving the green light to an empty road while motorists on a different route are stopped. This reduces the delay at intersections by providing the most effective green and red times and eliminate signal changing altogether if there is no demand from any particular part of the road intersections. However, a timer is frequently used as a backup in case the sensors fail in real-time strategy.

FUZZY LOGIC AND TRAFFIC CONTROL

The concept of fuzzy logic was conceived by Zadeh (1995), a professor at the University of California at Berkley and presented not as a control methodology, but as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership. Fuzzy logic is a technology that translates natural languages description of design policies into an algorithm using a mathematical model [6]. This mathematical model, implements the flexibility of human logic-abstraction and thinking in analogies in engineering solution. It consists of "fuzzification", fuzzy logic inference using IF-THEN rules and "defuzzification". Fuzzy logic is a problem solving control system methodology that lends to implementation in systems ranging from simple, small, embedded microcontroller to large, networked, multichannel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software or a combination of both. Fuzzy logic provides a simple way to arrive at a definite conclusion, based upon vague, ambiguous, imprecise, noisy or missing input information.

Fuzzy Traffic Controller

Fuzzy logic is known to be well suited for modeling and control of problems. The key motivation to wards fuzzy logic in traffic signal control is existence of uncertainties in signal control. The first attempt made to design fuzzy traffic controller was in 1970 by Pappis and Mamdani after which several other researchers like Yager and Filey [7], Thorpe [8] and Jarkko (2002) and several more, apply fuzzy logic in several ways. They all observed that fuzzy controller that fuzzy controller reduces the vehicle delay when traffic volume heavy. The main goal of fuzzy logic in traffic signal control are improving of traffic safety in intersection, maximizing the capacity of the intersection, minimizing the delays, clarifying the traffic environment and influencing the route choices.



General Structure of Fuzzy Traffic Signal Control

The fuzzy traffic controller operates by determining whether to extend or terminate the current green phase, based on a set of fuzzy rules and then the fuzzy rules compares the traffic conditions with the current green phase and traffic conditions with the next candidates green phase.

TRAFFIC LIGHTS CONTROL SYSTEM

Basically, there are two types of conventional traffic lights control system that are in used. One type of control uses a preset cycle time to change the lights. The other type of control combines preset cycle time with proximity sensors which can activate a change in the cycle time or the lights. In the case of a less traveled street which may not need a regular cycle of green lights, proximity sensors will activate a change in the light when cars are present. This type of control depends on having some prior knowledge of traffic flow patterns at the intersection so that signal cycle times and placement of proximity sensors may be customized for the intersection. Fuzzy logic traffic lights control is an alternative to conventional traffic lights control which can be used for a wider array of traffic patterns at an intersection. A fuzzy logic controlled traffic light uses sensors that count cars instead of proximity sensors which only indicate the presence of cars. This provides the controller with traffic densities in the lanes and allows a better assessment of changing traffic patterns. As the traffic distributions fluctuate, the fuzzy controller can change the signal light accordingly.

PROPOSED FUZZY INFERENCE BASED CONTROLLER

Kokkhiang and Rubiyah [9] proposed a fuzzy inference based traffic controller. In the design of the fuzzy traffic light controller, two main features considered are (i) to reduce the total delay time of waiting vehicles as well as to avoid heavy traffic congestion and (ii) to synchronize the local traffic controller with the neighbors, such as controlling the outgoing vehicles overruns the capacity of the intersections will be jammed. The fuzzy traffic lights controller is designed with a number of useful features not found in existing traffic lights controller. One example is that if there is a large volume of vehicles congested at a neighboring intersection, the number of vehicles coming into that intersection will be reduced. Three modules are proposed in the design of fuzzy traffic light controller. These are Next Phase, Green Phase Module and a Decision Module. Through the Next Phase and Green Phase Modules, the input which evaluates or processes the number of vehicles from the local detectors (detectors within the lane itself) and remote detectors (detectors from neighbor lanes) are considered. The Next Phase Module selects the most urgent phase among all the other phases except the Green Phase. The Green Phase Module observes the condition of traffic flow of the Green Phase only. The real Decision Module decides the urgency of degree between the Next Phase and the Green Phase Modules. It also decides by how long to extend the green phase signal or whether to change to other phases. For example, if the Green Phase Module is more urgent than the Next Phase Module, the green signal will be extended. On the other hand, if the Next Phase Module is more urgent than the Green Phase Module, the Decision Module will change the Green Phase signal to another phase.

METHODOLOGY

The method adopted for the design of the model desired is a combination of various design earlier discussed but modified to suit the road network, environmental condition and behavioral attitude of road users especially in Nigeria. Various papers, journals and designs are evaluated to achieve a model that solves the vehicle congestion problem in road intersections. The fuzzy model intended is basically a system and method for controlling traffic and traffic lights present at various intersections and junctions.

General Structure of a Fuzzy Traffic Lights Control System

This can be divided into two parts based on the functionality of the model. These are the Traffic Information Unit and the Central Control Unit. The traffic information unit is responsible for obtaining traffic information and it consists of component parts which are present at every road intersection. Traffic information gathered is transmitted to the central control unit which would not necessarily be present at the road side. In essence, various intersections in a metropolis or locality would have various traffic information units but one central control unit. The Central Control Unit of the fuzzy traffic lights control system is the second broad division of the system and as the name implies, it consists of component parts that is responsible for decision making and general control of the entire system. After traffic data is received from various traffic information units, the central control unit processes the data and sends the conclusion reached back to the traffic control unit to implement and take effect. In other words, the processed data is sent to the intelligent controller as traffic light phase-split control information which in turn transmits the information as communication signals to the receivers embedded in the traffic lights. Essentially, only one central control unit usually exists at a particular junction, intersection or road locality network but several traffic information units are present and each communicates with the central control unit in other to function effectively. The component parts of the central control unit include:

Operation of the Fuzzy Logic Traffic Light Controller Model

In operation of the present model, using a 4-lane traffic intersection as stated earlier: north, south, east and west; the downstream sensor located behind each traffic light counts the number of cars passing the traffic lights, and the upstream sensor which is located behind the first sensor counts the number of cars coming to the intersection at distance D from the lights. The number of cars between the traffic lights is determined by the difference of the reading between the two sensors. The distance between the two sensors D, is determined accordingly following the traffic flow pattern at that particular intersection and sent to the intelligent controller, and the intelligent controller transmits the data to central controllers. In the traffic lights controller two fuzzy input variables are chosen: the quantity of the traffic on the arrival side (Arrival) and the quantity of traffic on the queuing side (Queue). If the north and south side is green then this would be the arrival side while the east and west side would be considered as the queuing side, and vice-versa. The output fuzzy variable would be the extension time needed for the green light on the arrival side (Extension). The central controller determines the traffic congestion parameters using two fuzzy input variables: the quantity of the traffic on the arrival side (Arrival) and the quantity of traffic on the queuing side (Queue). The derived congestion parameters are input variable to one or more fuzzy logic controllers which derives traffic light phase-split control signals. The output fuzzy variable would be the extension time needed for the green light on the arrival side (Extension).

Thus, based on the current traffic conditions, the fuzzy rules can be formulated so that the output of the fuzzy controller will extend or not the current green light time. If there is no extension of the current green time, the state of the traffic light will immediately change to another state, allowing the traffic from the alternate phase to flow. Fuzzy logic is used to determine optimum traffic light phase split (i.e. the time split between red and green traffic light cycle) based on the traffic flow pattern, traffic information from the traffic information units and other factors. The optimum traffic light phase split is determined for each of the intelligent controllers. Fuzzy logic controllers are used to execute fuzzy logic inference rules from a fuzzy rule base in determining the congestion parameters and the appropriate action required.

Input and Output Membership Functions

Input variables and output variables are defined as members of fuzzy sets having degrees of membership determined by membership functions. The input variables are used to define the membership functions used by the fuzzy rule base. For the traffic lights control, there are four membership functions for each of the input and output fuzzy variable of the system. The two input fuzzy variables for the system are arrival and queue while the output variable is extension. The right hand notations in brackets are used to shorten these variables.

Arrival	Queue	Extension
Almost (AN)	Very Small (VS)	Zero (Z)
Few (F)	Small (S)	Short (S)
Many (MY)	Medium (M)	Medium (M)
Too Many (TMY)	Large (L)	Longer (L)

The graphical representation of the membership functions of the linguistic variables is presented in fig. 3. The y-axis is the degree of the membership of each of the fuzzy variable. For the input fuzzy variables, the universe of discourse (the x-axis) is the quantized sensor signals which sensed the quantity of the cars. For the output fuzzy variable the universe of discourse is the length of time to be extended in seconds. From fig. 3, six cars and above have been assigned a strong 'Too many' or 'large' fuzzy subsets in this simulation for arrival and queue input variables respectively which have a full membership. For 'many' or medium' fuzzy subsets, a full membership is 4 cars and so on. For the output fuzzy variables, a strong 'Long' fuzzy subset with a membership of '1' would be in the region of 6 seconds, whereas a strong 'Medium' fuzzy subset would be in the region of 4 seconds and so on. The configuration of these membership functions is done according to expert observation of the system and environment. However, the width and center of the membership functions of these fuzzy subsets can be easily changed and configured according to different traffic situations and conditions. For example if the junction is too congested, the number of cars in the fuzzy subset 'Too Many' or 'Large' needs to be increased. On the other hand, for a less congestion junction the width of the membership functions can be reduced. It can observed that in fuzzy logic control the transition from one fuzzy subset to another provides a smooth transition from one control action to another, thus the need to overlap there fuzz subsets arises. If there is no overlapping in the fuzzy subsets then the control action would resemble bivalent control (step –like action).on the other hand if there is too much overlap in the fuzzy subsets, there would be a lot of fuzziness and this blurs the distinction in the control action.

Fuzzy Rule Base

A reasoning mechanism is used to execute the fuzzy rule base and the fuzzy interference system. The fuzzy logic controllers execute fuzzy logic inference rules from a fuzzy rule base. The inference mechanism in the fuzzy logic controller resembles that of the human reasoning process. This is where fuzzy logic technology is associated with artificial intelligence. Humans unconsciously use rules in implementing their actions. The rule base for the model system and method is formulated with "IF…..THEN….." structure s representing the linguistic expression of the logical elements involved in the fuzzy logic rule base. The accuracy of the fuzzy model depends highly on how rules are defined .the execution of these rules using the defined rules base analyzes traffic congestion and decides on appropriate action. The beauty of fuzzy logic is the possible utilization of approximate reasoning in the rules sure as heavy, less, average, normal, longer, etc. Due to the membership assignment techniques as discussed, such linguistic variables, though fuzzy in nature, can be taken care of in the computer through fuzzy logic technology. Appropriate actions may be traffic control, or it may be appropriate traffic information distribution. The fuzzy logic controllers also use fuzzy logic to derive the phase-split control signals i.e. the fuzzy logic controller is responsible for controlling the length of the green time according to the traffic conditions. In the development of the fuzzy logic controller, specific rules are used and some examples are given below:

- If there are too many cars (TMY) at the arrival side and very small number of cars (VS) queuing then extend the green light longer (L)
- If there are few cars (F) at the arrival side and very small number of car (VS) queuing then extend the green light short (S).
- If there are almost no cars (AN) at the arrival side and very small number of cars (VS) queuing then do not extend the green light at all (Z).

These rules can be shortened as follows:

- IF Arrival is TMY AND Queue is VS THEN Extension is L.
- IF Arrival is F AND Queue is VS THEN Extension is S.
- IF Arrival is AN AND Queue is VS THEN Extension is Z.

From the above examples of the fuzzy rule base to be implemented for the model, the arrival and queue are the antecedents and extension of the green light is the consequent. Such rules can be easily developed according to the conditions of the traffic at the junction and a compact way to show these rules would be to use a matrix as shown in the fig below. The size of the matrix or the number of rules is equal to the number of input combinations derived from the number of membership functions per input. For example, in the traffic control system there are two inputs each having four membership functions, and then the number of rules would equal sixteen i.e. two to the power of four. In many applications it is not necessary to fill up all the rules in the matrix bank, however, for this application it is necessary. The number of input combinations derived from the number of membership functions per input which produces an output can also be represented in tabular form (Table 3.2) as a simplified representation of the matrix form.

Description of the program

Quantification of congestion is done using MATLAB (fuzzy tool) software to simulate the effectiveness of the fuzzy logic controller in controlling traffic condition at intersections in addition to other fuzzy inputs sent by the traffic sensor present at the road side .it is designed to work under the MATLAB environment and simple to debug and run provided the necessary data are supplied when requested for .the main program is written in sure a way that it calls three function which serve as the core of the entire program. Also available in the main program are codes that enable the plotting of tree graphs that allows the analysis and assessment of the enter system at a glance after simulation. The importance of the main program is that it ensure that the total simulation time for the enter program is not exceeded.

Fuzzy Logic System

Once the simulation starts, messages indicating the Particular lane or approach moving are displayed throughout the duration of simulation. This also means the second and third functions are being executed repeatedly. The fuzzy logic function which is the second function called in the main program executes the fuzzy rule base depending on the available data. This is done by implementing the generated rule list present in the function. The rule list simply contains the 16 rules possible under this model with each of the four membership functions of input variables (arrival and queue) and output variable (extension time) represented in numbers. For arrival, TMY is 4, MY is 3, F is 2 and AN is 1. For queue, L is 4, M is 3, S is 2 and VS is 1 while for extension, L is 4, M is 3, S is 2 and Z is 1. Therefore, the rule list contained in the fuzzy logic function is a representation of the fuzzy rule base in numbers. For example, the first rule set 4 1 4 1 1 implies 4 = membership function for first input (arrival); 1 = membership function for second input (queue); 4 = membership function for output (extension time); 1 = fuzzy weight (it's always one); 1 – rule's connection (AND=1, OR=2) but OR is not contained in the rules for this model thereby making it 1 all through also like the fuzzy weight.

Traffic Controller

The third and last function called by the main program is basically meant to use the fuzzy rules derived earlier to perform the actual traffic control at the intersections. Depending on the condition that has been met by the current traffic situation, the traffic control function decides if the current approach (i.e. north-south approach or east-west approach) that is moving would have an extension in the current green time light. If the north-south is the moving side (arrival) for instance and the flow-rate is higher, then the traffic controller would determine the necessary extension time. However, if the flow-rate at the queue (waiting side) exceeds that of the arrival, then the traffic light changes state immediately. Also, apart from having a higher flow-rate at the present queue, another condition which enables the traffic light to change state is when the current green light exceeds 20 seconds. From the above therefore, it can be stated that two conditions are necessary for there to be a change of state. These are:

- If the flow-rate at the queue exceeds the flow-rate at the arrival
- If the current green light time exceeds twenty seconds.

When any of the above conditions is met, then the traffic light changes state. If it is as a result of the second condition, then there is a possibility that the flow-rate at the previous moving side is still more than the flow-rate at the previous waiting side and there after two seconds or thereabout, there is a change of state back to previous state being experienced. This situation satisfies the models criteria that the minimum and maximum time of green light is 2 seconds and 20 seconds respectively. Hence, the traffic controller function forms a very important part of the program as it ensures that it assigns the arrival and queue values to the concerned approach or lane and ensures that a change of state is executed as at when due. This function also ensures that the correct green time length is undertaken and it is also responsible for displaying the message showing the lane moving currently.

RESULTS

There are three graphs generated after simulation time for the running of the program has been successfully exhausted. These graphs are important because they ensure proper analysis, assessment and evaluation of the entire system at a glance after simulation. The graph facility also allows the user to visualize and analyze the performance of the controllers graphically. The content of each graph is as a result of the prevailing traffic condition as presented by the flow-rates on each lane while trying to determine the flow density, move time and wait time as discussed below:

(i) Flow Density: The flow density shows the traffic flow-rate in each lane for every minute. Thus, the flow density graph shows the number of cars that have passed or gone through a particular lane in one minute. The number of cars here would not necessarily be the same as the flow-rate values used. However, the higher the flow-rate of a particular lane, the more the number of cars that passes the lane and therefore the higher the flow density. The flow density graph establishes the relationship between the number of cars that goes through the sensed portion of each lane at the intersection and the simulation time.

(ii) Moving Time: The moving time graph depicts the amount of time it takes the cars moving on each lane during every minute of simulation. In other words, this graph seeks to illustrate the time it takes the cars moving on the lanes plotted against the time of simulation. Unlike the flow density graph, the moving time graph has the four lanes (north, south, east and west) merged to make two lanes i.e. north-south lane as one approach and east-west lane as another approach, as it was done with the flow density graph.

(iii) Waiting Time: The waiting time graph is very similar in structure to the moving time graph. However, the data represented here has to do with the time it takes the cars queuing to wait during every minute of simulation on the north-south and east-west lanes. The duration of time it takes cars to wait is plotted against the simulation time for both lanes in the sample waiting time graph.

An important point observed in the three graphs generated is that while the output represented in the flow density graph remains the same for a particular set of input data or flow-rates, the output represented by both moving time and waiting time graphs changes after every simulation for the same set of input or flow-rates. What this means is that the moving time and waiting time for each of the lanes usually differs every time simulation is executed and that is why the graphs for both moving and waiting times are samples and are samples and are subject to change upon another simulation. This shows the flexibility of the traffic control program.

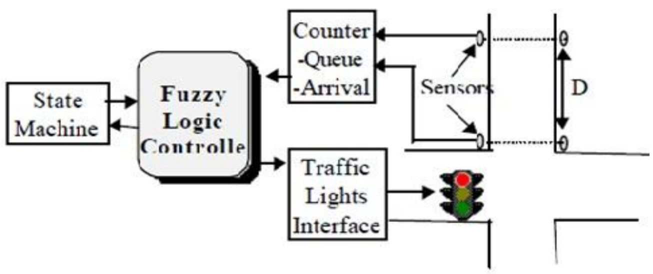
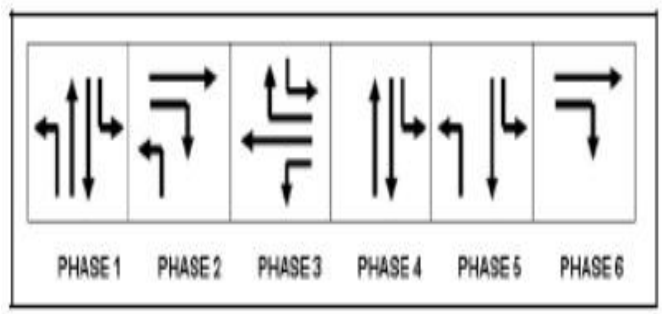
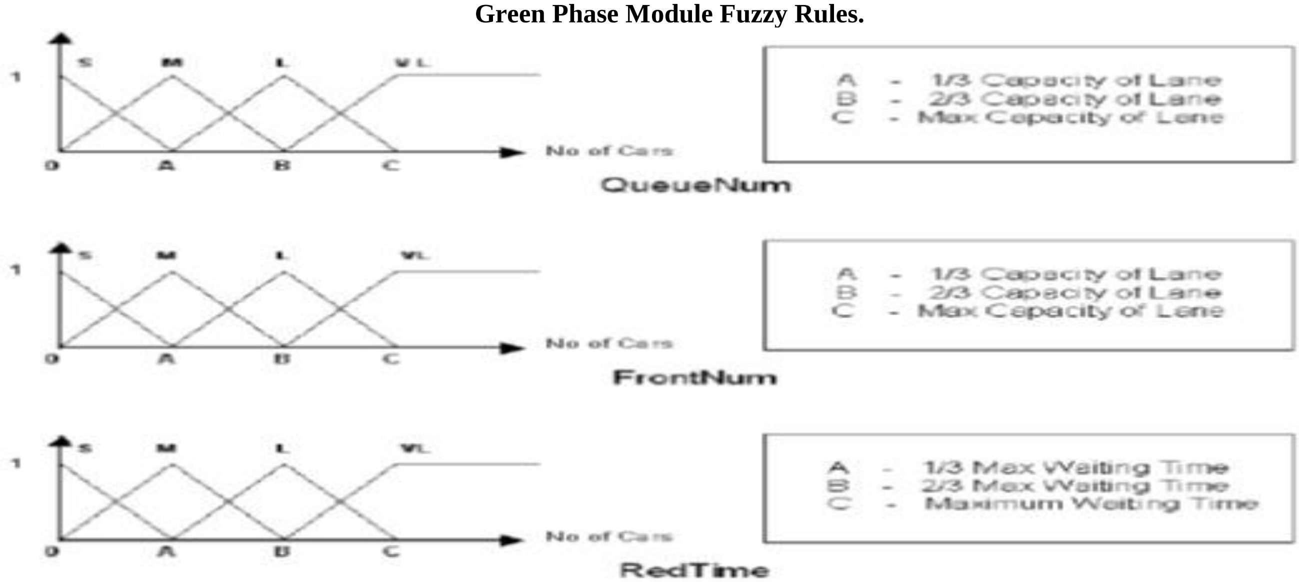


Fig. 1: A general structure of the fuzzy traffic lights control system

Figure 2. Figure showing six phases of a traffic lights cycle as proposed in the fuzzy controller.



Green Phase Module Fuzzy Rules.



RULE	INPUTS		OUTPUTS
	QueueNum	FrontNum	Extend
1.	Z		Z
2.	S	S	S
3.	S	M	S
4.	S	L	S
5.	M	S	L
6.	M	M	M
7.	M	L	S
8.	L	S	VL
9.	L	M	VL
10.	L	L	L

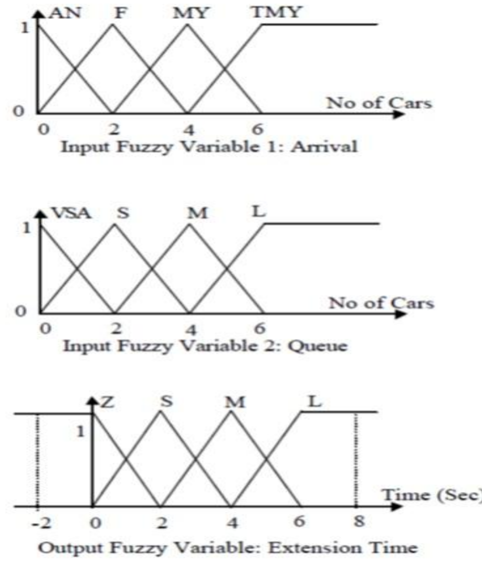


Fig. 3: Graphical representation of membership functions of the fuzzy logic controller

Figure 4

Arrival

Queue	AN	F	MY	TMY
VS	Z	S	M	L
S	Z	S	M	M
M	Z	Z	S	M
L	Z	Z	Z	S

DISCUSSIONS

The flexibility and dynamism shown by this program makes it and indeed the entire fuzzy traffic light control a better option to the other forms of traffic controllers, namely preset cycle time-controller and vehicle actuated controller. The flexibility here involves the number of vehicles sensed at the incoming junction and the extension of the green time. In a fixed-time controller, being an open-loop system, the green time is not extended whatever the density of cars at the junction. For vehicle actuated traffic light controllers, which is an enhanced version of fixed-time controller, the green time is extended whenever there is presence of a vehicle. However, these times are fixed in advance up to a maximum time limit. For example when a car is detected, the green time is extended until the maximum time is reached.

In the fuzzy logic controller, the extension time is not a fixed value. They are all fuzzy variables such as long, medium and small. The number of cars sensed at the input of the fuzzy controllers are also converted into fuzzy values, such as very small, small, medium, too many, etc. in addition to the fuzzy variables as mentioned, the fuzzy controller also has an advantage of performing according to linguistic rules in the manner of how a human would use. The reasoning method in the fuzzy controller is also similar to that of the policeman handling the traffic flow at a typical junction. The flow density of the simulation is varied according to real life traffic conditions. It can be observed from the results that the fuzzy logic control system provides better performance in terms of total waiting time as well as total moving time.

CONCLUSION

The fuzzy logic traffic light designed in this research is easy to be implemented and it is very cheap in terms of installation and maintenance compare to annual allowance of a road warden. This research is able to avoid giving passage to an empty road while there is congestion on the other routes which avoids unnecessary time wastage and reduces fuel consumption of motorist. Less waiting time will not only reduce the fuel consumption and mental stress experienced by drivers but also reduce stress of traffic warders, reduces road accident and also reduce air and noise pollution.

RECOMMENDATIONS

For further improvement on the efficiency and practical usefulness of this project work, more features need to be incorporated which are given below:

- Provision for emergency vehicles by integrating an interruptible signal which tends to give priority to special traffic such as ambulance, fire apparatus vehicles, police squad cars bullion vans and VIP cars.
- Drivers and passengers should remain patient as much as possible while experiencing delays as waiting time can only be reduced and minimized but cannot be total eliminated
- The fuzzy logic traffic control system is highly effective and should be integrated into our system gradually by traffic and government authorities.

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