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A Traffic Control and Offense Reporting System Using Fuzzy Logic

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Abstract- Traffic congestion is a severe problem in many modern cities and around the world. Due to these congestion problems, people lose time, miss opportunities, and get frustrated. As such, there is need to find ways of controlling this problem. In this work, we designed and developed an intelligent traffic lights control system, using fuzzy logic technology. A comparison was made between the fuzzy logic controller and the conventional fixed-time controller. Our Simulation result shows that the fuzzy logic controller performed better and is more cost effective. The methodology used to achieve this is the object oriented methodology and we used JAVA programming language to develop our system.

Keywords: Fuzzy logic; Traffic lights controller; Fuzzy variables; congestion

I. INTRODUCTION

Most traffic assignment models used to evaluate transportation networks considered only a single user class. However, assignment models have been provided to take account of variations in the cost functions, termed multi-class traffic assignment models. Most research work in developed countries leads to the development of traffic assignment models based on four or more wheeled motor vehicles, and generally, vehicle flows are considered in passenger car units (PCU). It is known that these models often produce inappropriate results when implemented in developing countries due to the very different traffic composition.

A conventional approach to transportation planning has four stages namely; trip generation, trip distribution, modal split and traffic assignment. Trip generation predicts the total number of trips in a study area. Trip distribution predicts a matrix of trip frequencies between production and attraction zones. Modal split estimates the division of trips between the different modes of transport and traffic assignment estimates traffic flow within the transportation network. The result of the last stage is essential for the transportation planner or traffic engineer to support decisions or policies relating to the transport infrastructure.

The road traffic assignment process selects the routes through the network used by vehicles travelling between all Origin-Destination, O-D pairs and loads the routes. The outputs of assignment are generally a set of link statistics, like link flows, costs or delays and possibly also path statistics, like path flows, costs or delays [1].

Link flows and path flows are then used to calculate an array of measures, which can be used, in turn, to evaluate the network alternative improvement and to assist in designing future transportation systems. The equilibrium approach is the most used in the traffic assignment process to represent the interaction between the demand and the supply of the transportation planning procedure.

Traffic congestion is a severe problem in many modern cities in Nigeria and around the world. Traffic congestion has been causing many critical problems and challenges in the major and most populated cities. To travel to different places within the city is becoming more difficult for the travelers in traffic. Due to these congestion problems, people lose time, miss opportunities, and get frustrated. Traffic congestion directly impacts on the companies. Due to traffic congestions, there is a loss in productivity from workers, opportunities are lost, delivery of goods and services get delayed on the road and thereby the cost goes on increasing.

To solve this delayed congestion problems, we have to build new facilities and infrastructure. The only disadvantage of making new roads on facilities is that it makes the surroundings more congested. So for that reason we need to change the system rather than making new infrastructure twice. The Main goals of this work are to provide safety, minimizing travel time and increasing the capacity of facilities [2]. It is to move a broad range of applications from basic traffic signal control system to advanced systems that provide operational benefits to the transportation system: reduce congestion, reduce operational costs, provide alternative to travelers, enhances productivity and increase the capacity of infrastructure [3]. Under these circumstances, the Traffic control on urban expressways is generally dependent upon the operators' judgment, For example, fully experienced operators are always working to optimize the traffic conditions, at the console desk in the traffic control center. The problems in the case of human traffic control are as follow:

- Only skilled operators can make suitable judgments and decision, because the situation is very complicated and many factors should be considered at control; the work load of skilled operators is very high, because they always make decisions according to traffic condition at very short time intervals.

➢ It is very difficult to improve the process of traffic control, because the actual process of the operators' judgment is not described clearly. The monitoring and control of city traffic is becoming a major problem in Nigeria. With the ever increasing number of vehicles on the road, the Traffic Monitoring Authority has to find new ways or measures of overcoming such a problem. The measures taken are development of new roads and flyovers in the middle of the city; building of several ring roads such as the inner ring road, middle ring road and outer ring road; introduction of restricting of large vehicles in the city during peak hours (i.e. early in the morning between 6.30am - 9.00am and evening 3.30pm-6.00pm). Also in the city of Rivers State, the registration of new vehicles each year increased by about twenty percent. This increment is rather alarming and even with the development of the new roads, other measures have to be stepped up and introduced as quickly as possible.

With effective control of the intersections, it is believed that the overall capacity and performance of urban traffic network could be resolved. There are several types of conventional methods for traffic signal control. However, they fail to deal effectively with complex and time-varying traffic conditions. Currently, two types of traffic lights control are commonly installed in Nigeria and many parts of the world. The Preset Cycle Time (PCT) and Vehicle-Actuated (VA). Due to the deployment of a large number of traffic police in the city during peak hours, it is evident that these types of traffic lights controllers are ineffective. Furthermore, they have been around for many decades and, thus, there is a need to research on new types of highly effective practical traffic lights controllers. In recent years, the fuzzy inference has been proven to be effective in the design of consumer products and industrial systems [4]. In traffic lights control, a number of researchers have applied the fuzzy control technique, however, in most cases only one intersection or traffic junction were considered. Many of these approaches are not suitable for the case of successively located traffic intersections or multiple intersections. In urban areas, many traffic lights are located close to each other due to the proximity of a number of intersections, thus, in order to solve traffic problems effectively, the system must be able to consider neighboring controllers and also the overall traffic situations. It becomes necessary to formulate the operators' judgment and to develop an automatic decision making control system in place of operators. If the system is established, a more effective traffic control process can be constructed and the actual situation of traffic control is investigated.

II. REVIEW OF RELATED WORK

Basically, there are two types of conventional traffic lights control system that are in use. 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. An actuated signal operates with variable vehicular timing and phasing intervals that depend on traffic volumes. The signals are actuated by vehicular detectors placed in the roadways.

The cycle lengths and green times of actuated control may vary from cycle to cycle in response to demands. Actuated controllers include semi-actuated, fully actuated, and density controllers, [5].

The VA-type consists of detectors which can activate a change in the length of phase. In this method, every road in the junction has a vehicle detector that detects the presence of vehicles at each of the junction. This method uses three parameters: Initial Interval, Extension Unit and Extension Limit [6].

Density operations, the controllers keep track of the number of arrivals and reduce the allowable gap according to several rules as vehicles show up or as time progresses. This type of controller also has a variable initial interval, thus allows a variable minimum green. Detectors are normally place farther back of the intersection stop line, particularly on high-speed approaches to the intersection of major streets [7].

III. ANALYSIS AND DESIGN

A fuzzy logic system is designed for an isolated four lane traffic intersections, North, South, East and West. In this proposed model, we consider two fuzzy input variables and one output fuzzy variable. These input variables are:

- Quantity of the traffic on the arrival side (Arrival);
- Quantity of traffic on the queuing side (Queue).

If the north and the south side is green then this would be the arrival side while the west and east side would be considered as the queuing side, and vice- versa. On the other side the output variable would be the extension time needed for the green light on the arrival side. So based on the current traffic conditions the fuzzy rules can be formulated so that the output of the fuzzy controller will approach to increase or not increase the current green light time. During these methods some points to be remembered are:

- The four traffic lights work in four sequences, every Light having a variable sequence from 5 to 120 seconds depending on the congestion (the number of vehicles from the queue but also the number of one's which arrive every minute);
- All the four traffic lights will be controlled by this same Mechanism;

If there is no extension of the current green light time, the state of the traffic lights will immediately change to another side which allows the traffic from the alternate traffic flow. In Fuzzy controller, the structures are:

Input 1 (I/P 1) is the arrival of the vehicles and

Input 2 (I/P 2) is the queuing of vehicles.

Which has two parameters that are used to set the extension time for green light fuzzified and then these parameters are given to fuzzy inference system which actually sets the time but fuzzy in nature which are actually different parameters (decrease, constant, increase) so to convert these performance parameters in crisp we use defuzzification method as shown in fig 1

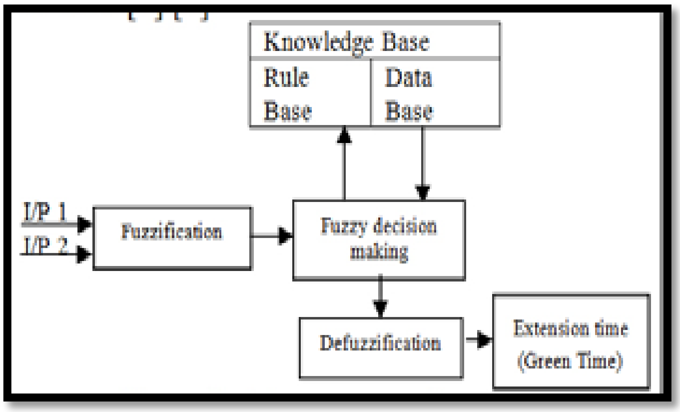

Fig. 1 Fuzzy controller structure (Akçelik, Besley, and Roper.2007).

IV. FUZZY CONTROLLER STRUCTURE

When the transportation needs is large, the signal cycle should be increased. The upper bound should not be more than 120 seconds generally, because the driver on the opposite direction may not tolerate that the signal cycle is more than 120 second. Minimum and maximum signal cycle is set for each phase. When transportation needs is small, the minimum signal cycle is run, on the other side when the transportation needs is large, the maximum signal cycle is the present cycle and traffic congestion is avoided [8].

V. FUZZY LOGIC TRAFFIC LIGHTS CON-TROLLER DESIGN

Fuzzy logic controller was designed for an isolated 4-lane traffic intersection: north, south, east and west as shown in Fig. 2. 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 west and east 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). 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 lights will immediately change to another state, allowing the traffic from the alternate phase to flow.

Fig. 2 Simulated output of the traffic junction using the developed software

VI. BRIEF DESCRIPTION ON USAGE AND SOFTWARE FACILITIES

The software has a number of facilities for easy user manipulation and also analysis of the performances of the fuzzy and fixed-time controllers. This section briefly explains the facilities available and information on how to use the software.

i) Controller

Upon starting the software, the user can choose the type of controller in the simulation. By using this menu the user may choose to simulate the performance of either (1) a fixed-time controller, or (2) a fuzzy logic controller or (3) both. The fixed-time controller is a conventional type of controller that is open-loop in nature. It uses a preset cycle time to change the lights. The default cycle time for the green, amber and red signal lights, respectively , are 11, 4, and 15 seconds. There is also an option for the user to change the cycle time to any desired value.

In choosing the fuzzy logic controller to control the traffic lights, the cycle time for the green lights is determined according to the density of the traffic. The user may set up his/her own fuzzy control rules or may use the default rules as given. There is also an option to configure the membership functions as desired. Using the third option, the software will simulate both of these controllers sequentially. First the fixed-time controller is simulated then followed by the fuzzy controller according to the set time as requested. This third option is mainly used for comparing the performance of the fixed-time and fuzzy logic controllers. To start the simulation the user has to define the type of controllers intended and configure the relevant parameters which are discussed below. Then by clicking the GO menu, simulation will actually start. The simulation can be stopped at any time by clicking the STOP facility.

ii) Real Time

The simulation software also provides real time control using a dedicated fuzzy micro-controller

iii) Cycle-Time

The cycle time is the time that the fuzzy controllers need to decide on the extension of the current green time period. It is not necessary to evaluate the system every second. This cycle time is dependent on the fuzzy rules and membership functions.

iv) Flowrate

Flowrate facility can be used to calculate the number of cars passing through a lane in one minute. The percentage of the flowrate is given by the following formula:

time (minutes)/car = 4*(100% / flow %)

The traffic flowrate can be set in two different modes. The user can set the flowrate by changing the scroll bar setting at the side of each lane. There is a facility where the user can set different flow rates at every minute. This facility is useful for determining how the controller will perform at a given intersection over the course of an entire day or some other time period.

v) Extension-Time

The actual green time extension in seconds for the output of the fuzzy logic controller is presented in the Extension-Time facility. These timings are generated automatically by the fuzzy logic controller and they are dependent on the settings of the membership functions and rules. Negative values in the table indicate immediate change. From the table, the user can determine whether the rules and membership functions have been well configured or not.

vi) Graph

The Graph facility allows the user to visualize and analyze the performance of the controllers graphically. There are seven types of plots that are available in this facility which are as follows:

- Car Sensed - shows the number of cars within the sensed area at each instant.
- Flow density - shows the traffic flowrate in each lane for every minute.
- Wait Time - shows the total waiting time of the cars at the junction for each lane for every minute of the simulation.
- Move Time - shows the total moving time of the cars at the junction for each lane for every minute of the simulation. Car In - calculates the number of cars moving into the sensed area in each lane for every minute of the simulation.
- Car Out - calculates the number of cars moving out of the sensed area in each lane for every minute of the simulation. Cost Function - provides numerical calculation of the cost using either of the controllers. A lower value indicates better performance of the controllers minimizing the waiting time and also fuel costs. This is calculated as follows: Cost = (Car In / Car Out)*(WaitTime / Drive Time)

vii) Restart

The Restart facility resets the simulation back to the initial state.

viii) Exit

This facility quits the simulation and brings the user back to the previous Windows environment.

VII. DESCRIPTION OF THE SOFTWARE

This software was written to simulate the effectiveness of the fuzzy logic controller in controlling traffic conditions at an isolated junction. The software was written in JAVA, using event-driven programming techniques and it is designed to work under the Windows environment. A mock junction is simulated in the software to show incoming and outgoing traffic. The software is highly graphical in nature and 'pop-up' and 'pull-down' menus are accommodated for easier user manipulation. The bulb and lines across each of the lanes show the sensors location. In real application, such sensors would be of the electromagnetic type embedded in the roads. Such sensor can easily detect vehicles such as cars, lorries, buses, etc. which are made of metals, through electromagnetic induction. Several analyses such as density of traffic, movement time, waiting time, cost, etc. can be made in the software using one of the available menus.

VIII. CONCLUSION

The reasoning method in the fuzzy logic based intelligent traffic light control system is also similar to that of the policeman handling the traffic flow at a typical junction. A simulation experiment was carried out to compare the performance of the fuzzy logic controller with a fixed-time conventional controller. The flow density of the simulation is varied according to real life traffic conditions. Therefore, it can be observed from the results that the fuzzy based intelligent traffic light control system provides better performance in terms of total waiting time as well as total moving time. Less waiting time will not only reduce the fuel consumption but also reduce air and noise pollution. Thus, the enhancement of traffic control systems by fuzzy logic greatly improves the reliability traffic control, to track traffic light offenders and record information about offender and label charges for such an offence.

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