DESIGN AND SIMULATION OF AN INTELLIGENT TRAFFIC CONTROL SYSTEM

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ABSTRACT

This paper described our research experiences of building an intelligent system to monitor and control road traffic in a Nigerian city. A hybrid methodology obtained by the crossing of the Structured Systems Analysis and Design Methodology (SSADM) and the Fuzzy-Logic based Design Methodology was deployed to develop and implement the system. Problems were identified with the current traffic control system at the '+' junctions and this necessitated the design and implementation of a new system to solve the problems. The resulting fuzzy logic-based system for traffic control was simulated and tested using a popular intersection in a Nigerian city; notorious for severe traffic logjam. The new system eliminated some of the problems identified in the current traffic monitoring and control systems.

KEYWORDS: Fuzzy Logic, embedded systems, road traffic, simulation, hybrid methodologies

I. INTRODUCTION

One of the major problems encountered in large cities is that of traffic congestion. Data from the Chartered Institute of Traffic and Logistic in Nigeria revealed that about 75 per cent mobility needs in the country is accounted for by road mode; and that more than seven million vehicles operate on Nigerian roads on a daily bases [1]. This figure was also confirmed by the Federal Road Safety Commission of Nigeria; the institution responsible for maintaining safety on the roads [2]. The commission further affirmed that the high traffic density was caused by the influx of vehicles as a result of breakdown in other transport sectors and is most prevalent in the '+' road junctions.

Several measures had been deployed to address the problem of road traffic congestion in large cities in Nigeria; namely among these are: the construction of flyovers and bypass roads, creating ring roads, posting of traffic wardens to trouble spots and construction of conventional traffic light based on counters. These measures however, had failed to meet the target of freeing major '+' intersections resulting in loss of human lives and waste of valuable man hour during the working days.

This paper described a solution to road traffic problems in large cities through the design and implementation of an intelligent system; based on fuzzy logic technology to monitor and control traffic light system. The authors will show how the new fuzzy logic traffic control system for "+" junction, eliminated the problems observed in the manual and conventional traffic control system through the simulation software developed using Java programming language. This paper is divided into five sections. The first section provided a brief introduction to traffic management in general and described the situations in urban cities. We reviewed related research experiences and results on road traffic systems in the second section. Particular attention was given to intelligent traffic control systems and several approached were outlined. While section three described the methodologies deployed in the development of the system, section four presented the research results and section five concluded the work.

II. REVIEW OF RELATED WORK

An intelligent traffic light monitoring system using an adaptive associative memory was designed by Abdul Kareem and Jantan (2011). 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. The program could determine all street cases with different weather conditions depending on the stream of images, which are extracted from the streets video cameras [3].

A distributed, knowledge-based system for real-time and traffic-adaptive control of traffic signals was described by Findler and et al (1997). The system was a learning system in two processes: the first process optimized the control of steady-state traffic at a single intersection and over a network of streets while the second stage of learning dealt with predictive/reactive control in responding to sudden changes in traffic patterns [4]. 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 centred 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 [5]. A framework for a dynamic and automatic traffic light control expert system was proposed by [6]. 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. A paper by Tan et al., (1996) described the design and implementation of an intelligent traffic lights controller based on fuzzy logic technology. The researchers developed a software to simulate the situation of an isolated traffic junction based on this technology. Their system was highly graphical in nature, used the Windows system and allowed simulation of different traffic conditions at the junction. The system made comparisons the fuzzy logic controller and a conventional fixed-time controller; and the simulation results showed that the fuzzy logic controller had better performance and was more cost effective [7].

Research efforts in traffic engineering studies 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, was 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. Among those techniques based on the queue model was a queue detection algorithm proposed by [8]. 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. A decentralized control model was described Jin & 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 [9]. 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 was propagated by Huang and Miller (2004). 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. The authors 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 [10]. Di Febbraro el al (2004) showed that Petri net (PN) models can be applied to traffic control. The researchers provided a modular representation of urban traffic systems regulated by signalized intersections and considered such systems to be composed of elementary structural components; namely, intersections and road stretches, the movement of vehicles in the traffic network was described with a microscopic representation and was realized via timed PNs. An interesting feature of the model was the possibility of representing the offsets among different traffic light cycles

as embedded in the structure of the model itself [11]. Nagel and Schreckenberg (1992) described a Cellular Automata model for traffic simulation. At each discrete time-step, vehicles increase their speed by a certain amount until they reach their maximum velocity. In case of a slower moving vehicle ahead, the speed will be decreased to avoid collision. Some randomness is introduced by adding for each vehicle a small chance of slowing down [12].
The experiences of building a traffic light controller using a simple predictor was described by Tavladakis (1999). Measurements taken during the current cycle were used to test several possible settings for the next cycle, and the setting resulting in the least amount of queued vehicles was executed. The system was highly adaptive, however as it only uses data of one cycle and could not handle strong fluctuations in traffic flow well [13]. 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 [14].

III. METHODOLOGY

A novel methodology was described in this work for the design and implementation of the intelligent traffic lights control system. This methodology was obtained as a hybrid of two standard methodologies: The Structured System Analysis and Design Methodology (SSADM) and the Fuzzy Based Design Methodology (Figure 1). The systems study and preliminary design was carried out using the Structured System Analysis and Design Methodology and it replaced the first step of the Fuzzy Based Design Methodology as shown in the broken arc in figure 1. The Fuzzy Logic-based methodology was chosen as the paradigm for an alternative design methodology; applied in developing both linear and non-linear systems for embedded control. Therefore, the physical and logical design phases of the SSADM were replaced by the two steps of the Fuzzy Logic-based methodology to complete the crossing of the two methodologies. A hybrid methodology was necessary because there was a need to examine the existing systems, classify the intersections as “Y” and “+” junction with the view of determining the major causes of traffic deadlock on road junction. There was also the need to design the traffic control system using fuzzy rules and simulation to implement an intelligent traffic control system that will eliminate logjam.

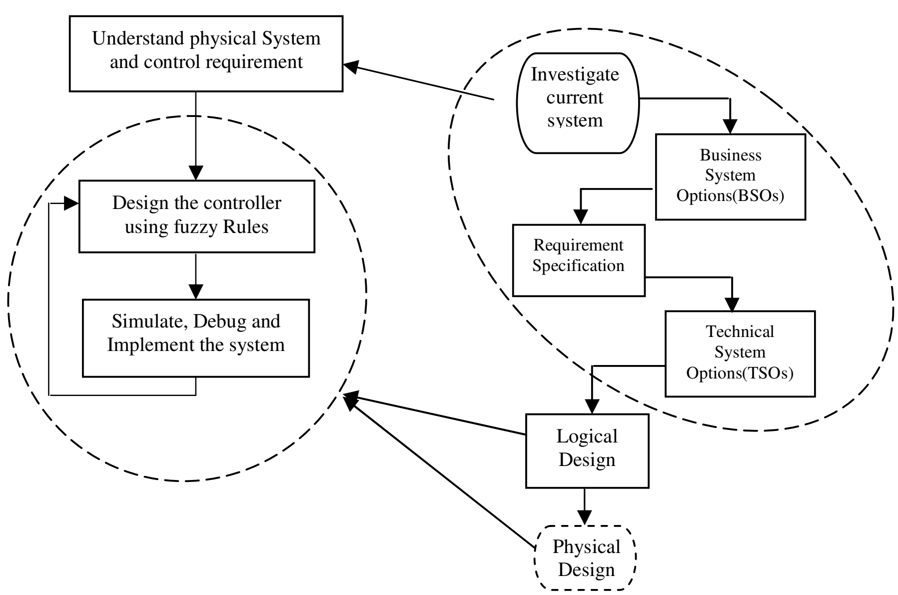

Figure1 Our Hybrid Design Methodology

An analysis of the current traffic control system in the South Eastern Nigerian city showed that some of the junctions are controlled by traffic wardens while some are not manned at all. Some of these junctions also have traffic lights strategically located but are not intelligent. These problems are inherent due to nonchalant attitude of traffic warders to effectively control traffic through hand signals. They could easily get tired as they are humans. Also, they can leave their duty post when the weather is not conducive to them. Cars in urban traffic can experience long travel times due to inefficient fixed time traffic light controller being used at the some junctions in the cities. Moreover, there is no effective intelligent traffic system that works twenty four hours (day and night) to effectively control signal at these busy junctions. In addition, aside from the manual control of traffic by traffic policemen, basically, there are two types of conventional traffic light control in use. One type of control uses a preset cycle time to change the lights while the other type of control combined preset cycle time with proximity sensors which can activate a change in the cycle time of the lights. In case of a less traveled street which may not need a regular cycle of green light when cars are present. This type of control depended on having a prior knowledge of flow patterns at the intersection so that signal cycle times and placement of proximity sensors may be customized for the intersection.

IV. RESULTS AND DISCUSSIONS

Based on our analysis of the present traffic control system, the following assumptions became necessary in order to develop a feasible system:

1. The system will only work for an isolated four-way junction with traffic coming from the four cardinal directions.
2. Traffic only moves from the North to the South and vice versa at the same time; and at this time, the traffic from the East and West is stopped. In this case, the controller considers the combination of all the waiting densities for the North and south as that of one side and those of the east and west combined as another side.
3. Turns (right and left) are considered in the design
4. The traffic from the west lane always has the right of way and the west-east lane is considered as the main traffic.

4.1 Results: Input / Output Specifications for the Design

Figure 2 shows the general structure of a fuzzy input output traffic lights control system. The system was modeled after the intelligent traffic control system developed at the Artificial intelligence centre, Universiti Teknologi Malaysia for the city of Kualar Lumpur, Malaysia by [7]. S represented the two electromagnetic sensors placed on the road for each lane. The first sensor was placed behind each traffic lights and the second sensor was located behind the first sensor. A sensor network normally constitutes a wireless ad-hoc network [15], meaning that each sensor supported a multi-hop routing algorithm. While the first sensor is required to count the number of cars passing the traffic lights; the second is required to count the number of cars coming to intersection at distance D from the lights. To determine the amount of cars between the traffic lights, the difference of the reading between the two sensors is evaluated. This differs from what is obtained in a conventional traffic control system where a proximity sensor is placed at the front of each traffic light and can only sense the presence of cars waiting at the junction and not the amount of cars waiting at traffic. The sequence of states that the fuzzy traffic controller should cycle through is controlled by the state machine controls the. There is one state for each phase of the traffic light. There is one default state which takes place when no incoming traffic is detected. This default state corresponds to the green time for a specific approach, usually to the main approach. In the sequence of states, a state can be skipped if there is no vehicle queues for the corresponding approach. The objectives of this design are to simulate an intelligent road traffic control system and build a platform independent software that is simple, flexible and robust and will ease traffic congestion (deadlock) in an urban city in Nigeria especially at "+" junction.

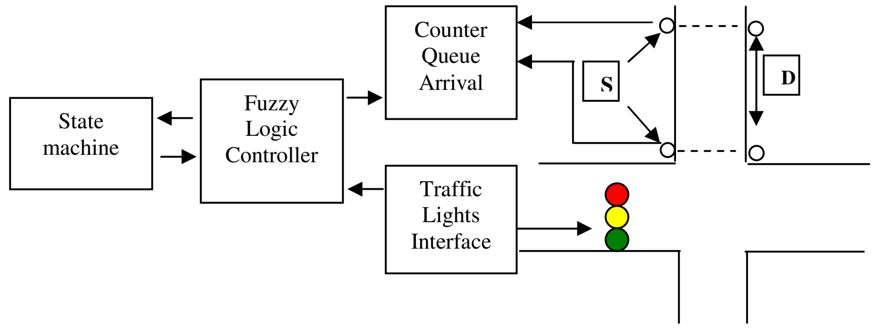

Figure 2 General structure of a fuzzy input/output traffic lights Control System

4.2 High Level Model and Modules Specifications for the System

Figure 3 shows the high level model of the system. The main module is the Traffic Panel and the main class traffic system is implemented using the java programming language. There are several methods that implement the intelligent traffic Light system such as changeLight, Calflow, TrafficPanel, PaintMode, PaintLightPeriod, PaintLights, Traffic System, Waiting, Moving, Flow density, Run, ActionPerformed and ItemStateChanged. These methods are interwoven into a complete interface that implements a total intelligent traffic control system. The main class trafficSystem, which is implemented using java programming language calls other methods already stated above. The changeLight module is overloaded with the function of toggling the lights (green to red and vice versa) depending on the signal passed to its executable thread. Calflow animates the objects (cars) on the interface using a flow sequence that depicts a typical traffic and a time sequence automatically generated by the system timer (measured in milliseconds), taken into consideration the number of cars waiting and the time they have been on the queue. Traffic panel initializes the interface parameters such as frames, buttons, timer, objects and other processes (threads) that run when the interface is invoked by the applet viewer command. On the other hand, PaintMode, PaintLight, PaintRoad, PaintLights are modules which draw the objects(Cars), lights, roads(paths) for traffic flow and graphs for traffic count and toggling of traffic lights. These modules implement the various functionalities of the graphic interface or class library.

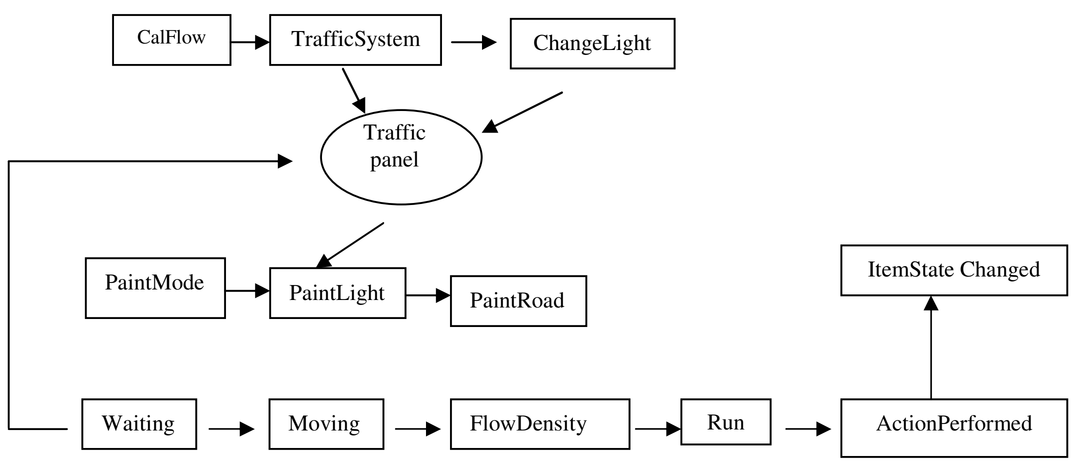

Figure 3 High level model of the traffic control system

It is worth mentioning here that the attributes of a typical car object are initialized by class node defined at the beginning of the code. Such attributes as the X and Y co-ordinates of the car object, the line, road and delay of the car object are all encapsulated in class node. The class is inherited by other classes to implement the entire system. Traffic system class initializes the buttons that start and end the traffic light simulation. The start and end processes commence and terminate the traffic flow and light sequence respectively. The modules for the commencement and termination of the traffic control process are bound to these controls at run time. This is achieved by implementing class ActionListener that listens to a click event on a specific button. Each click event invokes ActionEvent that retrieves the label on each button to determine which button is being invoked. This allows a comprehensive control of operations on the interface without deadlock. Waiting module enables the program to plot graph for waiting time of cars. Moving class also plots the graph for moving time of cars both in conventional traffic control system and fuzzy logic traffic control system. Flow density module checks the car density of every lane that is, checks which lane has more cars before it gives access for movement. Run class multithreads the traffic light. It controls the Go and Stop button. ActionPerformed class is responsible for loading the applet in browser. ItemStateChanged class ensures that car sensors are not deselected thereby making the program work efficiently. Finally, the traffic control system simulates the complete functionality of a real time traffic light and provides a user friendly interface for easy implementation. The overall internal context diagram for the system is shown in Figure 4.

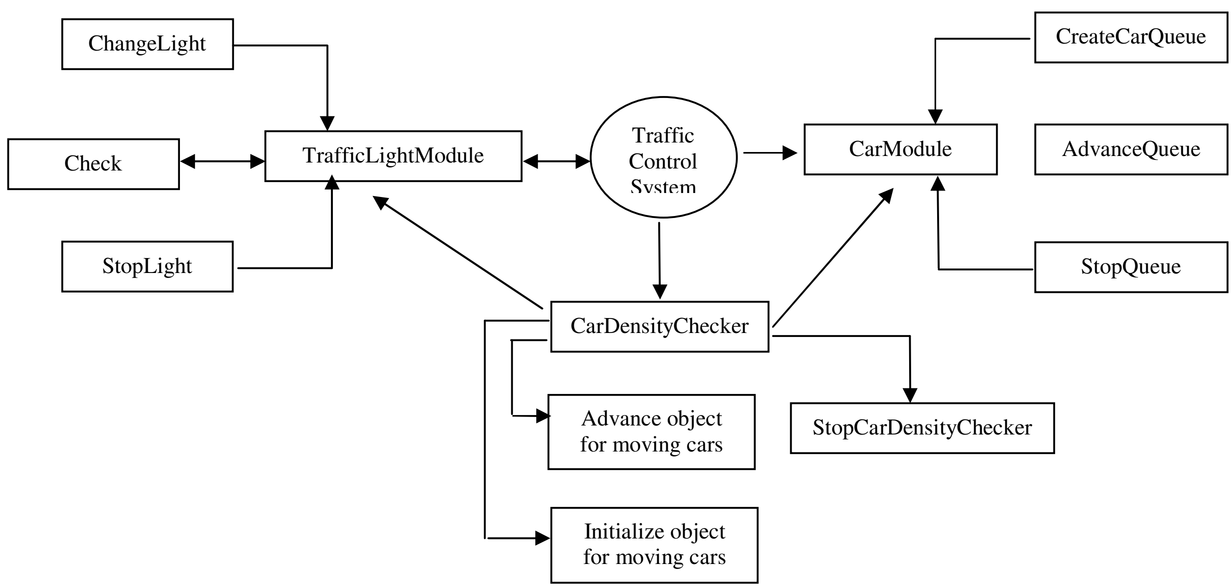

Figure 4 Overall internal context diagram for the system

4.3 Simulation of the Traffic Control System

Java SE 6 Update 10 was the tool deployed for building the simulated version of the traffic control system. This choice was based on the feature that the Java is the researchers' language of choice in developing applications that require higher performance [15]. The Java Virtual Machine, (JVM) provided support for multiple languages platforms and the Java SE 6 Update 10 provided an improved performance of Java2D graphics primitives on Windows, using Direct3D and hardware acceleration. Figures 5 shows control centre for the simulation of the traffic control system.

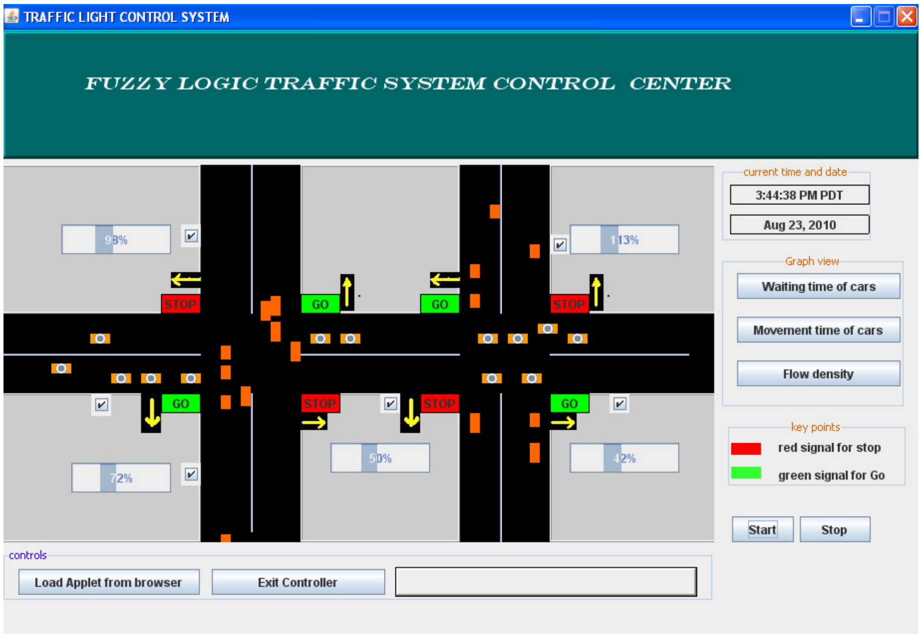

Figure 5 The simulated fuzzy logic traffic control system

The system is highly graphical in nature. A number of pop-up and push-down menus were introduced in the implementation for ease of use (figure 5). Command buttons to display graphs showing waiting time of cars (Figure 6), Movement time of cars (Figure 7), car flow density (Figure 8) and current arrival/departure times were all embedded in the application's control centre. The views can be cascaded to show the control centre and any of the graphs at the same time (Figure 9). Two fuzzy input variables were chosen in the design to represent the quantities of the traffic on the arrival side (Arrival) and the quantity of traffic on the queuing side (Queue). The green side represented the arrival side while the red side is the queuing side. To vary the flow of traffic in the simulation according to real life situations; the density of flow of cars is set as required by clicking on the arrows on the sides of each lane.

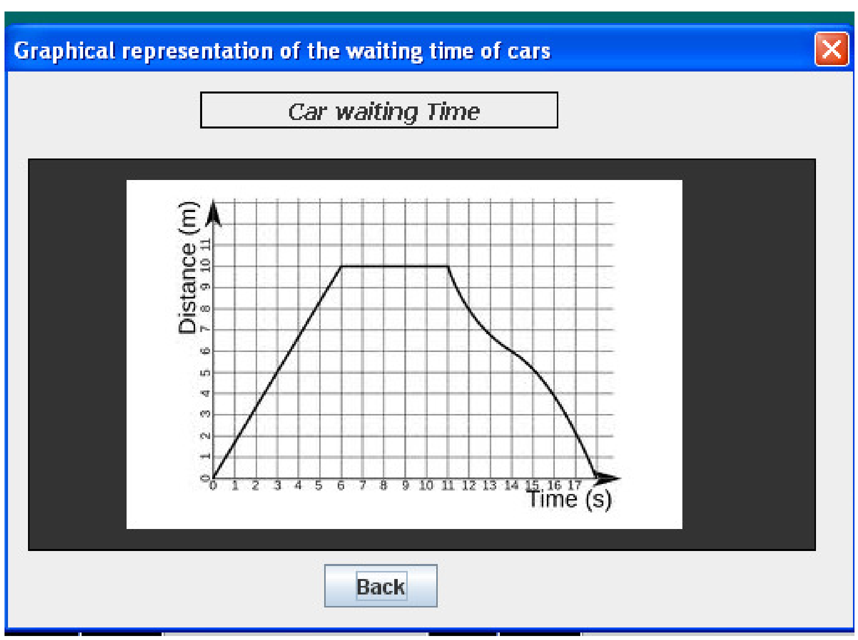

Figure 6 Car waiting time in the simulation

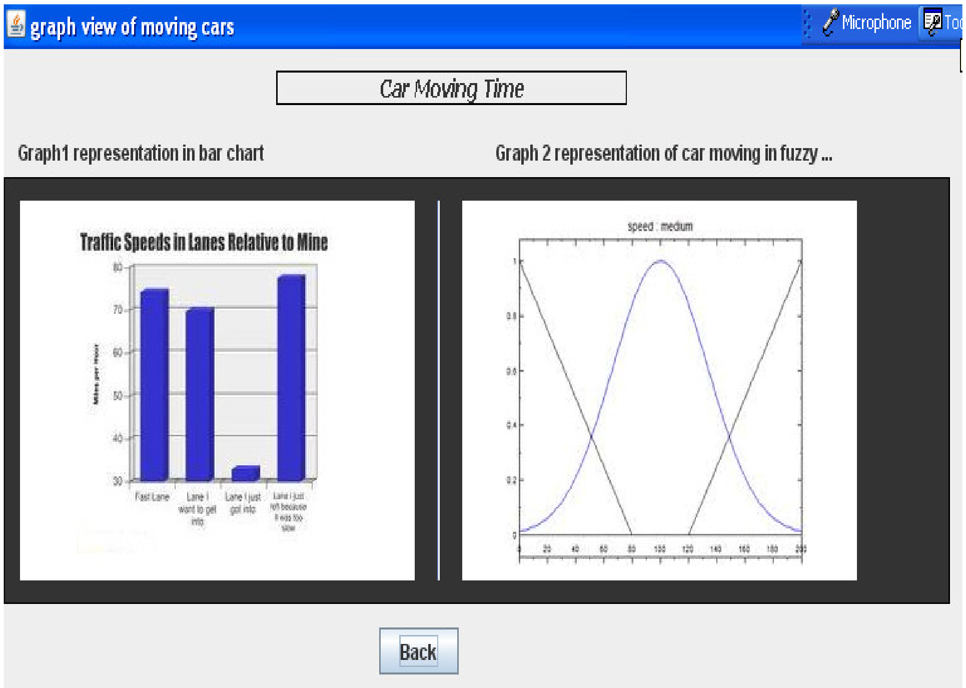

Figure 7 Car moving time in the simulation

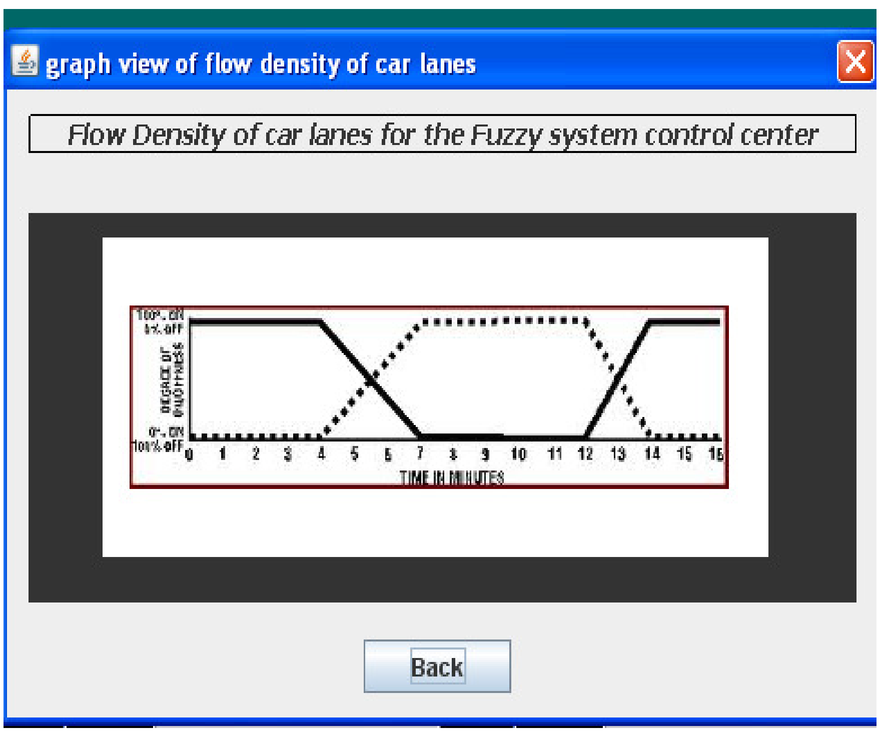

Figure 8 Flow density of cars in the simulation

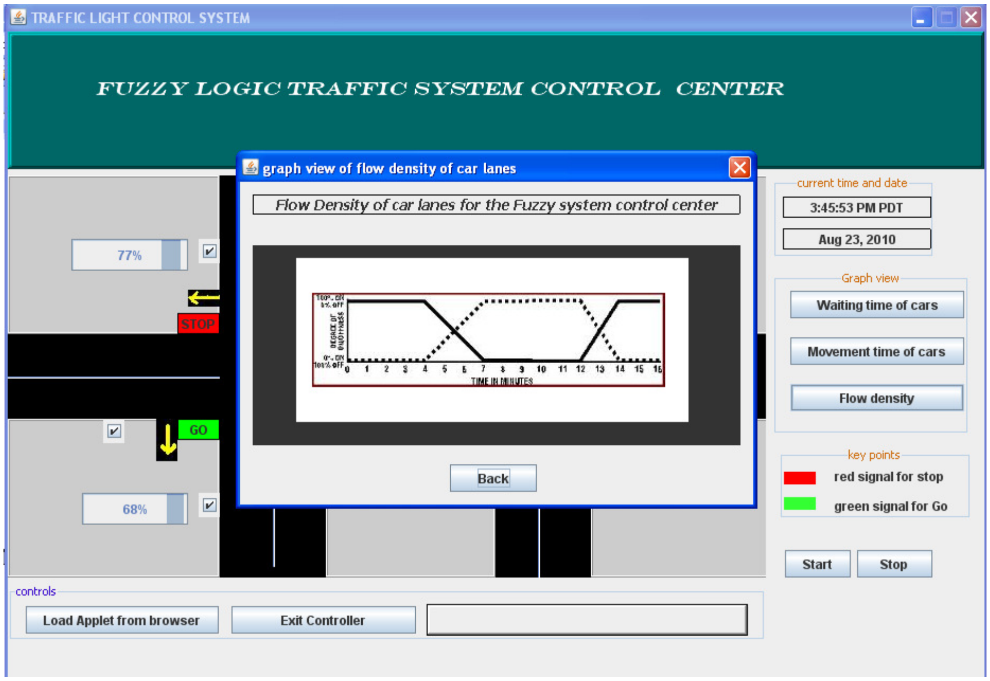

Figure 9 Cascading different views of the traffic control system

V. CONCLUSION

Information technology (IT) has transformed many industries, from education to health care to government, and is now in the early stages of transforming transportation systems. While many think improving a country's transportation system solely means building new roads or repairing aging infrastructures, the future of transportation lies not only in concrete and steel, but also increasingly in using IT. IT enables elements within the transportation system—vehicles, roads, traffic lights, message signs, etc. to become intelligent by embedding them with microchips and sensors and empowering them to communicate with each other through wireless technologies [16]. The researchers in this work, attempted to solve the problems of road traffic congestion in large cities through the design and implementation of an intelligent system; based on fuzzy logic technology to monitor and control traffic lights. An analysis of the current traffic management system in Nigeria was carried out and the results of the analysis necessitated the design of an intelligent traffic control system. Figures 5 through 9 shows the outputs of a Java software simulation of the system developed using a popular '+" junction in an eastern Nigeria city; notorious for traffic congestion. The system eliminated the problems observed in the manual and conventional traffic control system as the flow density was varied according to real life traffic situations. It was observed that the fuzzy logic control system provided better performance in terms of total waiting time as well as total moving time. Since efficiency of any service facility was measured in terms of how busy the facility is, we therefore deemed it imperative to say that the system under question is not only highly efficient but also has curbed successfully the menace of traffic deadlock which has become a phenomenon on our roads as less waiting time will not only reduce the fuel consumption but also reduce air and noise pollution.

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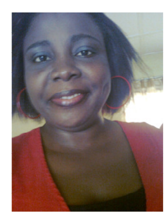

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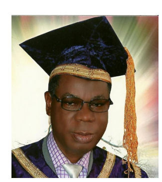

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