An Embedded Fuzzy Logic Based Application for Density Traffic Control System

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ABSTRACT

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The control of density traffic at cross junction road usually manned by human efforts or implementation of automatic traffic light system. This system seem and proves to be inefficient with some challenges. The major constraints of this traffic control are as a result of the inability of most traffic control systems to assign appropriate waiting time for vehicles based on the lane density. Also with little or no consideration for pedestrians, emergency and security agents priorities. In view of this, an intelligent density traffic control system using (fuzzy logic) which is capable of providing priority to the road users based on the density and emergency situations was developed and presented in this paper. This system will obtain the approximate amount of vehicle and presence of pedestrians respectfully on each lane with help of Infrared Sensors (IR) and siren detection system for emergency and security road users. The working principle of this system depend on the logic inputs rules given into the processing unit by the (sensors, S1 and S2) which helps the system to generates a timing sequence that best suit the number of vehicles and pedestrians available on the lane at point in time. The results obtained indicate significant improvement, since average response time of the fuzzy rule based density traffic control is achieved at 0.45 seconds; thereby eliminating bottlenecks or delays at traffic junction

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I. Introduction

The advent of traffic light control mounted at intersecting streets or cross junction helps to control motorist traffic and reduce collision of road users, due to advance technology in the development and implementation of embedded traffic light control system. The road accident has been a pathetic, rampant and unbearable situation to the peoples of Africa especially in West Africa (Nigeria) due to some circumstances like heavy traffic, impatient, inefficient traffic control agent and system implementation.

Traffic can be defined as the movement of people and goods through a pathway from one destination to another. In order to meet every day movement of the people through the defined routes, required development of an artificial intelligent traffic control system with a specified rules that will govern the operational of the control system [1]. This will reduce the delays and potential of accident occurrences whenever vehicles from different roads attempt to access other routes that intersect at the same time. Increase in the population and the number of vehicles plight roads in the major cities give rise to several traffic challenges that beyond the control of human traffic agents or automatic traffic light system [2]. Different methods have been adopted to ensure smooth flow of traffic with the use of most common methods; uniform traffic control warden/agent and the electronic traffic control system.

The use of a uniform public officials to control or regulates the flow of vehicle and enforces parking restrictions on the highway has been the most popular method of traffic management. This method has been termed to have alternative in developing cities when considering factors such as behavior of motorist, overall acceptance of innovation by the society and significant drawbacks which arise from fatigue, changes in weather, etc. as alter the performance of the individual.

Another method employed in the control of vehicles traffic flow is the electronic traffic light control which has the capability of directing vehicles to and fro from different lanes on a junction by assign fixed timing for particular lane to reduce traffic congestion based on its capability.

Overtime, efforts have been made to develop fully intelligent systems to curb these problems arising from traffic controller inefficiency, but majority of the automated traffic control systems today are operating on pre-assigned or predetermined timing sequence [3]. In most cases, the green light of a particular lane is activated without little or no road user presence and there are a lot of vehicle delay or emergency on the other lanes which kept waiting for long time, this makes such systems to be inefficient in traffic and congestion control.

Embedded system with wireless facilities, sensors integrated on single-on-chip (SoC) devices play a vital roles in the development of an intelligent systems based traffic controls and others [4, 5]. This system build with limited CPU, memory and power resources networked will enhance the communication, connectivity and system operation.

II. Related Works

Several methods has been proposed in this area but most of them have limitation in one way of the others which leading to couples of new proposed techniques. Recently, an incorporated Infrared (IR) sensors with embedded system is developed to managing the flow of vehicle traffic at the road junction [6, 7]. This system help to detect the presence of vehicles whenever the signals between the IR transmitters and IR receiver sensors are interrupted by the movement of vehicles. The microcontroller made decisions and update the delay time accordingly based on available vehicle on the lane. Emergencies or security road user is not considered as well as pedestrian.

In [8, 9], an application of intelligent traffic control system using PLC is proposed, this help to control movement of the vehicle at cross junction. The author's improvement based on the allotted time to each lane which proved to be efficient but other road users are not considered. The system is able to sense the presence of vehicles from a certain range of distance and using mathematical functions to calculate the appropriate delay time for every lane depending on the specified priorities. This system is efficient in traffic lane monitoring but not a multifactor system.

An ant colony based optimizer techniques proposed to improve on the traffic congestion in a city by [10]. This work introduced a new structure of urban traffic control system, which adopt ant colony optimizer techniques to increase the efficiency of the traffic control system. But, emergency case of road user and security agents are not considered. A web intelligent traffic management system is proposed by [11]. This system was designed to utilize internet facilities for remote monitoring and control of traffic in the cities. The embedded web server technology GUI is developed to communicate through central traffic management unit for selecting particular nodes to observed and monitor the operation of the traffic lights and density at the corresponding nodes.

In the approach of [12, 13], fuzzy logic traffic controller which dynamically controls the timing of the traffic light and phase sequence to reduce congestion is developed. The system result shows 25% decreased in average delay of vehicle stopping at the intersection with 6% improvement on total controllers. This approach does not considered cases of emergency, security agent and pedestrian of road user.

In [14, 15, 16, 17], proposed a fuzzy traffic control system using fuzzy logic rules and image processing approach to determine the amount of vehicle waiting during the RED light ON/waiting phase and the frequency of arrival during the GREEN phase. The inputs logic rule depend on the amount of automobiles on each lane to the point of intersection using cameras, and the number of the detected vehicle is transmitted to the controller for immediate action. Also, min-max inference procedure and centroid defuzzification strategy is employed to get the value for the green-light time

duration as the output. But the other issues such as pedestrians crossing and the presence of emergency vehicles on the road contribute to vehicular traffic congestions does not consider.

Due to all identified shortcoming of the electronic traffic control systems and traffic agents, the authors developed an intelligent density traffic control system using fuzzy logic application for density traffic lane detection and given priority to the emergency road users. Two different sensors was employed for the suitable implementation of the system (infrared and siren detection sensor).

III. Materials and Methods

A fuzzy logic controller system based on density traffic control is developed with integration of several hardware components and software design in Arduino IDE using C language and MATLAB based fuzzy environment. The hardware design comprises of power section, sensing unit, controller unit and signal display unit. The system prototype model utilize regulated power supply of +3.3 V and +5V embedded with the ATmega development board.

A. Sensing unit

The sensing unit includes the IR sensor (transmitter and receiver) which helps to detect the presence of the vehicle on the lanes and calculate based on the density before priority will be given. Also siren detection sensor is implemented for sensing and detection of ambulance, security agents or emergency road users. ATMega328P chip with crystal oscillator of 16MHz is used in the system timing based on the fuzzy logic rules programmed in the system unit. The signal display unit consist of red, amber and green color light to control the direction and flow of vehicle movement as depicted in the block diagram of "Fig. 1".

The active detector intensity of infrared sensor decreases depend on the exponential relationship of Beer-Lambert principle which given as expressed in "(1)". The active detector output depends on the change in corresponding output voltage, $(V_0 - V)$ as expressed in "(2)".

$$I = I_0 e^{-klx} \tag{1}$$

$$\mu_a = \frac{(V_0 - V)}{V_0} = \frac{(I_0 - I)}{I_0} = 1 - \frac{I}{I_0}$$
 (2)

where, μ_a is fractional light absorbance, I and V is target infrared sensor intensity output, I₀ and V₀ is initial infrared detector intensity output, e is exponential relationship, k is absorption coefficient constant, 1 is equivalent optical path length between the IR sensors, and x is concentration of light detector. But, if k and l are kept constant, the fractional light absorbance can be given as "(3)".

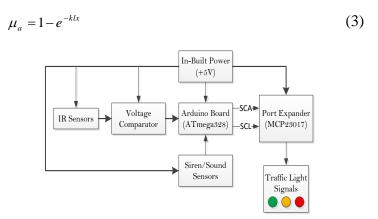


Fig. 1. The system block diagram

The system circuit design is simulated, implemented and tested virtually in the computer aided design software tool called proteus virtual simulation modelling (PVSM) before bread-boarding and implementation on the printed circuit board as illustrated in "Fig. 2, 3, & 4".

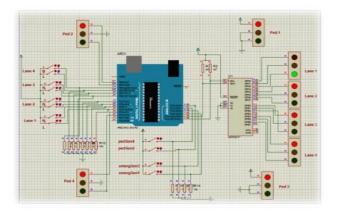


Fig. 2. Simulated system circuit design

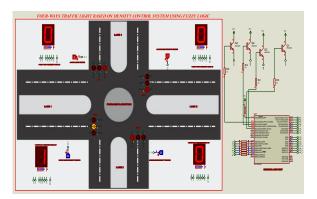


Fig. 3. Architecture design of 4-ways traffic control system

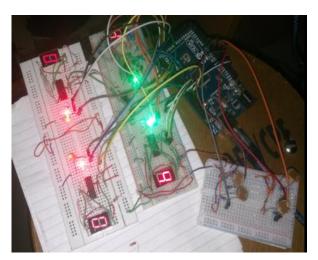


Fig. 4. Breadboard of cross junction traffic control system

B. Fuzzy logic controller unit

The fuzzy logic controller and the mathematical operation of the logical variable system based on the analog input values and the digital values is designed as in "Fig. 5". This fuzzy control system required an adjustment to improve the fuzzy mechanism performance as given in "(4)" and "(5)".

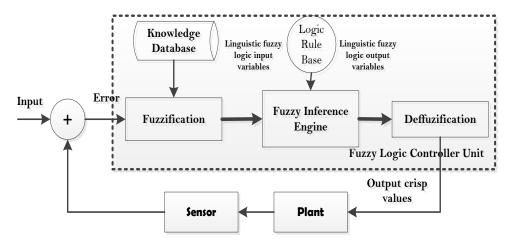


Fig. 5. Fuzzy logic traffic control system

$$\theta^{(n)} = \alpha(P_0, P_1, P_2, P_3..., P_n)$$
 (4)

$$\theta^{(n)} = \alpha(\theta^{n-1}, P_n) \tag{5}$$

Where $\theta^{(n)}$ is a set of parameter to be adjusted at time $t = T_n$, and P_n is the parameter collected at time T_n .

C. Fuzzy logic rules and its operation

Fuzzy logic is a generalized logic techniques based on many valued rational or concept, which beyond binary logic of two different valued (0 or 1, true/false, high/low, ON/OFF etc). Fuzzy is a reasoning based on recognition of a logical statements which does not depend only on either true or false but range from certainty to unlikely (0.0 to 1.0). The fuzzy logic flow diagram is depited in "Fig. 6", and the mathematical parameterization of controller system based on the fuzzy rules are expressed as follows.

$$\begin{aligned} Rule1 - IF \ S_1(T_n) &\in S_2 AND ... AND \ S_i(T_n) \in S_{2i} \\ THEN\beta_1(T_n) &= K_{11}S_1(T_n) + K_{12}S_2(T_n) + K_{1i}S_i(T_n) \\ Rule2 - IF \ S_1(T_n) &\in S_{21} AND ... AND \ S_i(T_n) \in S_{2i} \\ THEN\beta_2(T_n) &= K_{21}S_1(T_n) + K_{22}S_2(T_n) + K_{2i}S_i(T_n) \,. \\ Rule \ j - IF \ S_1(T_n) &\in S_{k1} AND ... AND \ S_i(T_n) \in S_{ki} \\ THEN\beta_i(T_n) &= K_{i1}S_1(T_n) + K_{i2}S_2(T_n) + K_{ii}S_i(T_n) \end{aligned}$$

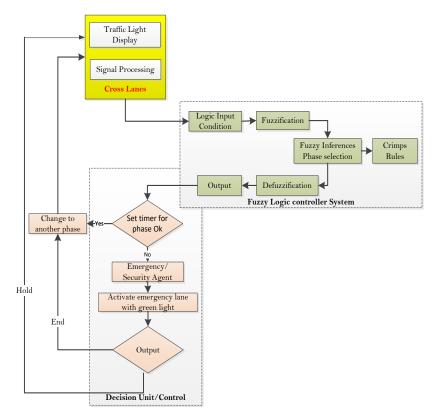


Fig. 6. Fuzzy logic flow diagram

The two sensors (S1) and (S2) are deployed to each lane as illustrated in "Fig. 4" to detect presence and density of the vehicles in each lane, in order to assign appropriate time (AT) for vehicle movement. The input variable of these sensors are mapped by three fuzzy sets which are; LOW, MEDIUM and HIGH. The rules applied on the input fuzzy sets are as follows.

- If S1 is LOW and S2 is LOW, then AT is LOW.
- If S1 is LOW and S2 is MEDIUM, then AT is LOW.
- If S1 is LOW and S2 is HIGH, then AT is MEDIUM.
- If S1 is MEDIUM and S2 is LOW, then AT is LOW.
- If S1 is MEDIUM and S2 is MEDIUM, then AT is MEDIUM.
- If S1 is MEDIUM and S2 is HIGH, then AT is MEDIUM.
- If S1 is HIGH and S2 is LOW, then AT is MEDIUM.
- If S1 is HIGH and S2 MEDIUM, then AT is MEDIUM.
- If S1 is HIGH and S2 is HIGH, then AT is HIGH.

D. Software design in matlab environment

The program design for cross junction traffic control is developed in Arduino IDE using c language for programming of the intelligent controller, as well as MATLAB R2015 for the fuzzy inference of the system controller. The fuzzy rules development for density traffic control based on the traffic congestion at cross junction lanes, security/emergency road users and pedestrian are considered in the designed. "Fig. 7" illustrate the graphic user interface of fuzzy logic set rules design.

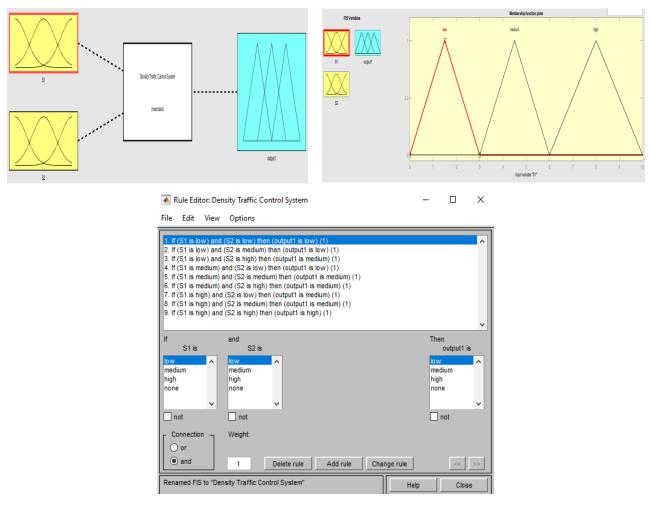


Fig. 7.GUI of fuzzy logic set rules

E. Prototype design and implementation

The fuzzy logic based density traffic control prototype is presented in "Fig. 8" and it made up of 3x3ft wooden board, turf grass material, cardboard, strawboard, makers gums and tapes. This model represents a four lane express way with two infrared sensors on the two right lanes approaching the junction. Each sensor is made up of a transmitter and a receiver placed opposite to each other across the road with siren/sound sensor detection.



Fig. 8. Complete functioning system prototype

IV. Results and Discussion

This system prototype is tested both virtually and real life scenario as illustrated in "Fig. 3" and "Fig. 4" above based on the fuzzy logic rules predefined. The number of vehicles on a particular road is determined based on the sensitivity of sensor position in a particular lane. It prove be efficient, accurate and intelligent based on the fuzzy rules and programming of the chip which is adjustable and reprogramming. "Fig. 9" depicts the result of fuzzy rule based traffic control system output at pre-set time. The number of vehicles on the road constitutes (high, moderate or low) traffic scenario and different periods of 15 seconds for high density vehicles, 10 seconds for moderate vehicles, 10 seconds for pedestrian and 0 second for empty lane sequences assigned for different scenarios. Also, priorities is given to the arrival of emergency or security convoy as soon as arrival of siren/sound detected by interrupting the activated lane timing and assign moderate timing of (10 seconds) for their movement. Table 1 shows the system performance based on fuzzy rule, Table 2 analyse the traffic light control information. "Fig. 10" and "Fig. 11" depicts a fuzzy logic results for low, moderate and high density traffic conditions.

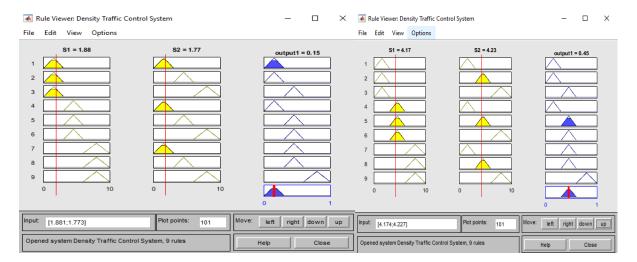


Fig. 9. Fuzzy rule for traffic control output

S1	S2	AT
0	0	0.50
1.42	1.5, 4.5, 8.05	0.15, 0.15, 0.45
2.98	3.05	0.15
4.54	4.59	0.45
6.01	5.95	0.45
8.03	8.05	0.80
9.95	10.0	0.50

Table 1: Fuzzy rule result analysis

Table 2: Traffic light control information

Traffic Density	HIGH	MODERATE	EMPTY
Number of Vehicles	4	2	0
Green Light Period for Vehicles	15 Sec	10 Sec	0 Sec
Maximum Waiting period for Vehicles	45 Sec	30 Sec	0 Sec
Green Light Period for		10 Sec	
Pedestrians			

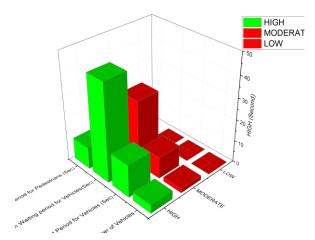


Fig. 10. High traffic scenario

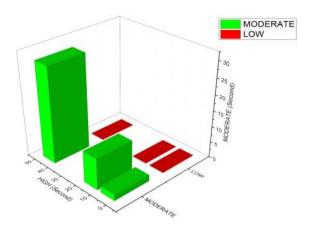


Fig. 11. Moderate traffic scenario

V. Conclusion

In this paper, the design and development of an intelligent traffic control system that can detect vehicle from different lanes and adequately route vehicular traffic to and fro from lane with minimum time has been presented. The hardware of this system which comprises of four main sections namely; input, control, power supply and output section has been developed and tested for desired functionalities. The system is connected to graphical user interface to enable monitoring and manual control in case of adjustment or malfunction of any section of its units. The results obtained indicate significant improvement when compare to the conventional traffic control system, the average response time of the fuzzy rule based density traffic control is given as 0.45 seconds; thereby eliminating bottlenecks or delays at traffic junction.

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