# Anfis-Based Intelligent Traffic Control System (ITCS) for Developing Cities

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***Abstract*—Intelligent Traffic Control System (ITCS) is needed to effectively control the flow of traffic on major road networks in developing cities. The ITCS system resolves the limitations of traditional traffic control systems which assign fixed green time, and give inefficient control in unforeseen traffic situations. Artificial Neural Network (ANN) techniques can be used to optimize the flow of traffic at a traffic junction, based on real-time information of traffic volume on different lanes. In this work, we present a novel traffic control scheme- ITCS- with machine learning abilities. The Intelligent Traffic Control System (ITCS) consists of Closed-circuit television (CCTV) cameras that take photograph of each traffic lane in real time, and send to the Image Processing unit which determines the volume of traffic on that particular lane. The ITCS then assigns a priority to each lane based on the current traffic volume on it. The priority weights can be adapted in real time, and are capable of responding to traffic changes caused by unforeseen events. The Adaptive Neuro-Fuzzy Inference System (ANFIS)-based traffic control system can learn from past traffic data and can predict future traffic on a particular road, by observing the traffic on the adjoining roads. The ITCS system will help to alleviate traffic congestions on major city roads and reduce unproductive time, economic stagnation, and green house emissions in smart cities.**

***Index Terms*—intelligent traffic control, ANFIS, real-time traffic, softcomputing, smart cities**

## I. Introduction

The developments in Artificial Neural Network (ANN) has been applied in solving several Engineering control problems which involves the optimization of decision making processes. Traffic lights control is one of such area in which ANN techniques can be applied to effectively control the flow of traffic at a traffic junction, based on real-time traffic volume on each road (lane). Existing traffic control systems assigns a fixed time for each lane, without considering that some lanes have heavier traffic than the others. Some control schemes assigns varying time for specific lanes based on expectation of high traffic volume on those lanes. However, unpredictable human activities, events or occurrence that leads to blockade of some lanes are not put into consideration in these schemes. For example, a normally traffic-light road can develop high traffic, if an alternative route is temporally inaccessible, and motorist decides to use it.

In this work, we present a novel traffic control scheme- Intelligent Traffic Control System (ITCS) with machine learning abilities. The ITCS consists of Closed-circuit television (CCTV) cameras that take photograph of each traffic lane in real time, and send to the Image Processing unit which determines the volume of traffic on that lane. The ITCS then assigns a priority to the lanes based on the current traffic volume on each. The priority weights can be adjusted in real time, and is capable of responding to traffic changes caused by unforeseen events. Fig. 1 shows the CCTV image of a traffic lane at an instant of time.

Figure 1. CCTV Image of a traffic lane

## II. Literature Review

Adaptive signal control systems have been used to capture the performance of the traffic system in uncertain situations. Signal control systems with learning abilities are the best to handle uncertainties issues. The main challenge of learning-based signal control systems has to do with the learning efficiency.

In past works, Artificial Intelligence (AI) techniques have been applied with fuzzy control method for intersection control. Dubey A. *et al* [1] proposed an Internet of things based traffic monitoring and control system which allows a central traffic control office to continually monitor and control flow of traffic in a traffic junction over the internet. Xiao et al in [2] applied visual sensing technology to the intelligent traffic control system. The authors in [2] designed CCD camera with 5 million resolution and used it to analyze real-time traffic entering at each intersection of urban road. Traffic parameters such as the vehicles length, average waiting time were used to calculate the traffic volume of each lane and queue, and to

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provide real-time data to the signal light control system for dynamic signal parameter configuration to achieve intelligent single-point light signal control, trunk control and regional control. Awoyera *et al.* in [3] propose a sustainable plan for urban transport in megacities in Africa. The authors advocate for the adoption of "green" travel modes to reduce the environmental impacts in urban areas. The work recommends policy approach in the form of discouraging of automobile use, encouraging of bicycle use, increased investment into rail and mass transit system, and increasing the cost of land, to achieve sustainable transport in African and other developing cities. In [4] Duofo *et al.* studied the rapid transit strategy of the intelligent control system and the optimal planning problem. Macroscopic optimization method of road traffic network, and the simulation of comfort index (LOS), traffic volume and safety index was carried out. Their results show that intelligent traffic control can overcome the negative factors such as delay response time, asymmetry of human body and visual restriction. In addition, the intelligent network gives better performance than traditional traffic control. Janani *et al.* in [5] propose an android-app based system for enhancing ambulance service which usually gets affected by road traffic congestions in highly crowded metropolitan cities. The authors propose a system that creates an android app that connects both the ambulance and the traffic signal station using cloud network. The system uses radio frequency identification (RFID) technology to implement the intelligent traffic signal control. The system is built on the basic idea that, if the ambulance halts on the way due to a traffic signal, RFID installed at the traffic signal tracks the RFID tagged ambulance and sends the data to the cloud. On acknowledgement for the user through the mobile app, the specific signal is made Green for some time until the ambulance passes, after which it resumes the original flow of sequence of signaling. The proposed system finds the ambulance spot and controls the traffic light to pass it, thus saving time and acting as lifesaver in emergency periods. Robert *et al.* in [6] employ a computer vision system to facilitate the identification of traffic violations committed in the road intersection. The architecture includes three sub-systems: video capture sub-system, intelligent operating architecture (IOA) sub-system, and output sub-system. The IOA manages different algorithms for vehicle detection and tracking, plate number localization, plate character recognition, and traffic violations identification. The system addresses traffic violations such as number coding, over-speeding, and swerving. In [7] Jaya et al proposed a new method of determining the number of traffic on the road. They employ a method which computes the amount of area occupied by vehicles on the road rather than finding number of vehicles by detection of vehicle edge. The traffic data obtained by this method is then used to automatically control the traffic signaling in a sequential manner depending on the amount of traffic on the road. Qing-Jie *et al.* in [8] present a streamlined parallel traffic management system (PtMS) which works alongside an intelligent transportation system. The PtMS's structure provides enhanced control and management support, with increased versatility for real-world use scenarios. Akanbi *et al.* in [9] present a fuzzy logic system which incorporates important personnel (VIP) movement to an intelligent traffic light controller system. The system inputs are traffic quantity, waiting time and siren intensity. The results from simulation on sample traffic data show that the system was able to accord the VIP movement its desired priority at the cross junctions thereby reducing the possibility of VIP movement causing accident at the junction. In [10], Wang et al present a summary of developments in integrated intelligent control and management system for urban traffic systems in China. The work examines key technologies which include hierarchical intelligent control systems, agent-based control (ABC) and Artificial Transportation Systems (ATS) for network-enabled traffic operational systems. The integrated system considers surface street intersection signal control, freeway/road entrance/exit ramp metering, and integrated traffic network control, guidance, and management. Rahman *et al.* in [11] applied Neuro-fuzzy technique to control the flow of traffic at road intersections in uncertain situation. Rotake *et al.* in [12] presents an intelligent traffic signal control (ITSC) system with flexibility of modification on real time application. The ITSC system consist of high-performance, low power AVR_32 microcontroller with 32kbytes of in-system programmable flash memory and in-built 8-channel, 10-bit ADC which is required to process the IR input from sensor network. The ITSC system will able to deal two basic problem of traditional traffic light system, which are Detection of traffic volume by using genetic algorithm, and emergency vehicle detection such as ambulance, police etc. by using wireless sensor network (IR) embedded at the signal intersection. Adaptive traffic control system is the most efficient to achieve low delay at traffic intersections. However, there are less traffic signal controllers developed using the Adaptive Neuro-Fuzzy Inference System (ANFIS) controller.

## III. Methodology and Implementation

In this work, ANFIS-Based control is applied to a traffic light system at the intersections of an isolated four lane. The control is achieved by observing the vehicles' waiting time and vehicles' queue length at each of the four phases in real-time. The markov queuing process is used to model the traffic intersection. The typical four-lane intersection is shown in Fig. 2.

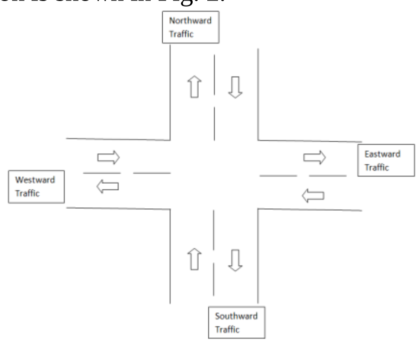


Figure 2. Typical four-lane traffic intersection

The intersections permit eight movements through the lanes. Based on the M/M/1 queue theory, vehicles queue and are served on first in first out (FIFO) principle. A single server is required to generate the traffic signal, which changes the next phases of the traffic light in turn, and assigns green time extension based on the volume of traffic and vehicle waiting time.

The process of assigning extension green time to the phases is modeled by fuzzy reasoning or fuzzy inference system (FIS). Fuzzy reasoning is composed of the following steps:

1. Measure the adaptability of the premise of the rules for a given input i.e. the degrees of conformity
2. From the adaptability obtained in the preceding (1), infer the conclusion of each rule
3. Aggregate the individual conclusion to obtain the overall conclusion

The rule consequent part uses the Sugeno-Type FIS. First order Sugeno-Type FIS is used in ANFIS traffic signal controller. The first order Sugeno-Type FIS employs a linear system for the output membership function which follows the rule illustrated below:

If Input 1 = x and Input 2 = y,

then Output is $z = ax + by + c$,

where "a", "b", and "c" are rule consequent parameters which are determined using least square estimation method.

In the Traffic Control System,

Input 1 (x) = Traffic Waiting Time, Wt (0 – 50 seconds)

Input 2 (y) = Traffic Queue Time, Q (0 – 50 vehicles)

Output (z) = Traffic Green Light Extension Time, Et (0 – 5 seconds)

The linear system Output, $z = ax + by + c$,

where, a and b are weights determined using least squares.

We adopt weights of $a = b = 0.025$, and constant $c = 2.5$ in the simulation.

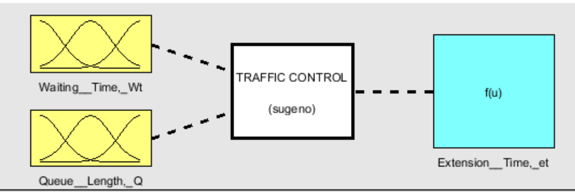


Figure 3. Fuzzy logic control for Intelligent Traffic Control System (ITCS)

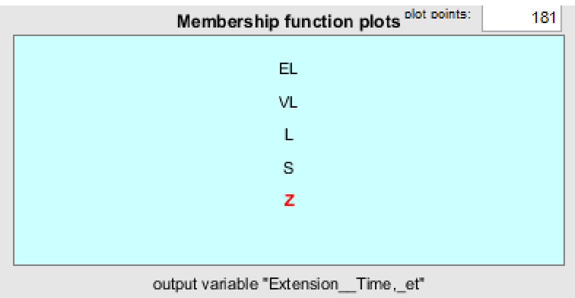


Figure 4. output (Green Light Extension Time) 0 – 5 seconds

The Traffic control is implemented according to the methodology described above in MATLAB Simulation environment. The network design is shown in Fig. 3, the Output membership function plot for Green Light Extension Time 0 – 5 seconds is shown in Fig. 4, while the ANFIS model is shown in Fig. 5.

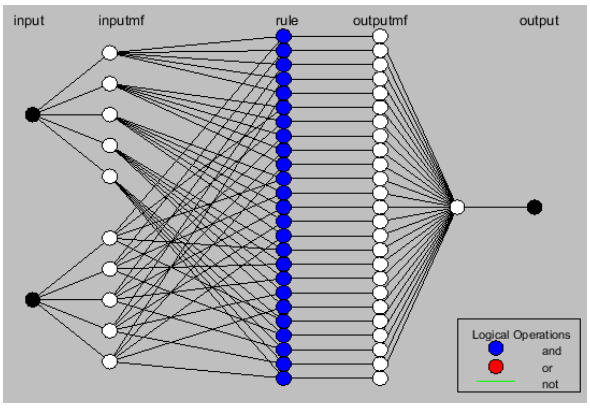


Figure 5. ANFIS model structure

The inputs membership functions are specified for the vehicle waiting time, Wt and queue length, Qt and output membership functions for the green extension time Et.

The performance of ANFIS traffic signal controller is optimized by training it with a set of input-output sample data to learn the rule consequents parameters and tune the membership functions. The FIS is trained using the hybrid optimization method. By this method, the membership function parameters are trained to emulate the training data. The training data is shown in Fig. 6.

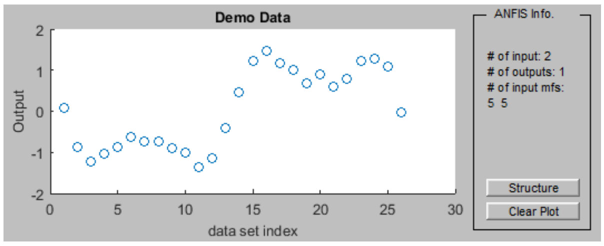


Figure 6. Training data

## IV. Results and Discussion

The simulation test results are shown in Figures 7 through 10. The adaptive neuro-fuzzy inference system output is shown in Fig. 7. For a vehicle queue length of 30 vehicles and waiting time of 5 seconds, the ANFIS-based system computes a green time extension of 3.38 seconds, as shown in Fig. 7. An algorithm written in C language and compiled on MATLAB is used to determine the next phase of traffic flow. The algorithm run on the next phase module, to determine the lane that is to be passed after the current extension green time elapses. The Next phase module result is shown in Fig. 8. For sample vehicle queue lengths of 12, 6, 30 and 9 vehicles on the Eastward, Southward, Westward and Northward lanes respectively, the Next phase is determined to be Phase3- Westward lane due to its high traffic volume of 30 vehicles as compared to the other lanes. Fig. 9 and Fig. 10 represents the surface plots of the two inputs and single output functions. As shown in Fig. 9, the green time extension increases gradually to a maximum of 5 seconds, as the queue length and waiting time of vehicles increases.

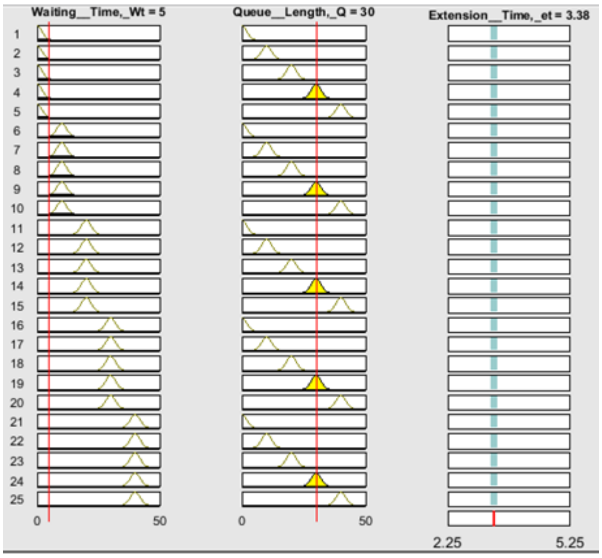


Figure 7. Fuzzy rules and extension green time

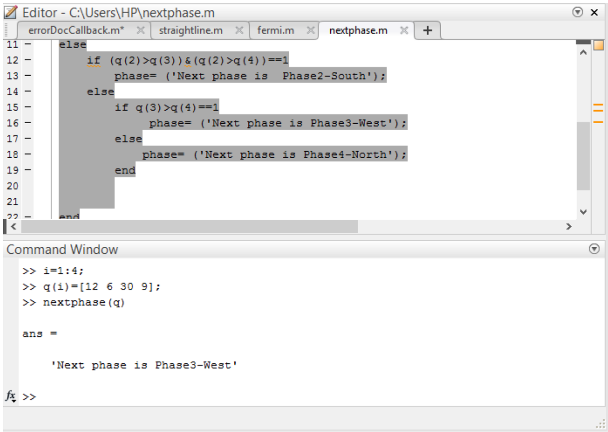


Figure 8. Next phase module program run

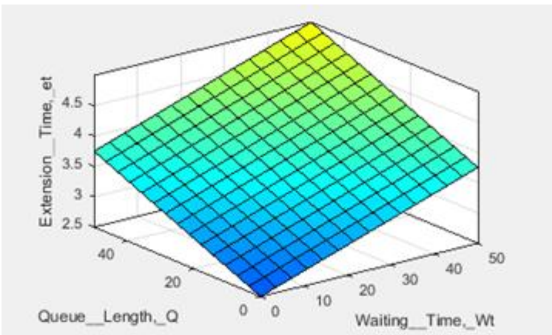


Figure 9. Surface views for FIS outputs

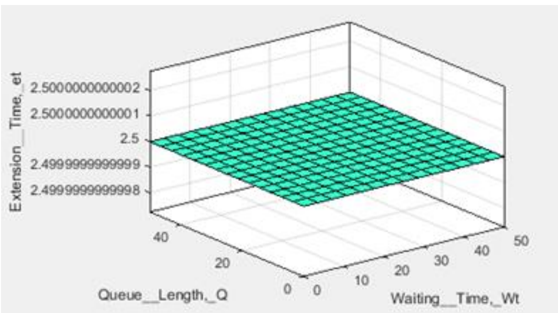


Figure 10. Surface view for ANFIS

TABLE I. PERFORMANCE OF THE SYSTEM

| Performance Measures | ANFIS Controller | FUZZY Controller | NEURAL Controller | TRADITIONAL (FIXED) Controller |
|---|---|---|---|---|
| Average Queue length | 15.43 | 23.67 | 30.21 | 45.04 |
| Average Waiting time | 3.38 | 8.51 | 12.15 | 24.20 |
| Average delay | 22.11 | 37.45 | 49.22 | 60.18 |

The performance of the ANFIS-based traffic controller is compared to fuzzy-based, neural-based and traditional (fixed) traffic controller systems in terms of three measures. The performance measures used are average queue length, average waiting time and average delay of vehicles at each of the four lanes on the isolated traffic intersection. The performances of each controller types are shown in Table I.

ANFIS traffic control system gives lowest average vehicles queue length, average waiting time and average delay time at all of the four lanes on at the isolated junction, while fuzzy traffic control system gives the second lowest average vehicles queue length. The traditional traffic control system gives the highest average queue length, average waiting time and average delay at all of the four lanes of the junction. Therefore, Fuzzy and ANFIS traffic signal controller produce good performance measures as compared to the traditional traffic signal controllers. Fuzzy and ANFIS traffic signal controller are able to skip the phase where there is no vehicle detected on the lane and assign the right of way to vehicles on other lanes. By this means, shorter average vehicles queue length on each approach at the traffic junction can be obtained. Moreover, the simulation results show that the average vehicles queue length, average waiting time and delay time of ANFIS controller are lower than that of fuzzy controller. The ANFIS controller outperformed the fuzzy controller because ANFIS traffic controller can adapt to the real time traffic condition at all time. ANFIS traffic controller has the ability to learn from a set of input-output sample data to tune its input and output membership functions. The membership functions can be tuned to optimize performance based on real time traffic conditions.

## V. CONCLUSION

In this work, an Artificial Neural Network approach to monitor and control the flow of traffic at an isolated road junction has been presented. ANFIS was used to estimate the green time extension for markov traffic arrival and queuing process, at road sections whose traffic information are not available. ANFIS traffic control system has better performance compared to fuzzy control system, due to ANFIS' ability to adapt the membership functions in response to traffic conditions, whereas the membership functions of fuzzy control system are developed based on human knowledge. Therefore, ANFIS controller gives better accuracy in terms of extension time than fuzzy controller. Present work considered real time traffic control for a single road junction under unpredictable environments. In future work, we will consider several road junctions which form a part of road networks in a city. We will be able to adapt traffic control not only based on observed traffic on a single road, but also based on traffic conditions on adjoining roads. In this way, the system will be able to learn and control traffic to forestall traffic congestions on major city roads and reduce economic downtimes and pollution.

## VI. Recommendations

Traffic management extends beyond controlling vehicles, but also pedestrians and emergency vehicles e.g. ambulance, fire-fighting vehicles as well as public transport. An integrated traffic control requires simplified and innovative methods for sensing and distinguishing between the different traffic types. For example, antenna-based sensors can be used to transmit and receive signals from emergency vehicles so that lanes having these vehicles can be given priority by the controller module. Other means of identification of pedestrians and cyclers such as ultrasonic sound transmission and reception can be employed in an integrated traffic system. For a robust and effective traffic management and future planning, all lanes and intersections of major cities' roads need to be connected to each other and a central traffic control office. The interconnected traffic management system will be able to manage all of the different systems and integrate them to an Internet of Things (IoT) Network. This will serve as a reliable source of traffic survey data, and enable city planners and researchers to study and analyze traffic patterns easily. This will also help to reveal latent real-time traffic problems and to come up with an effective solution. Intelligent traffic monitoring and control system is an essential component of smart city planning.

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