Smart Traffic Control Using Adaptive Neuro-Fuzzy Inference System(ANFIS)

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Abstract: -Use of automobiles is increasing throughout the world, particularly in large urban areas. There has been the problem of traffic congestion with the increase in the number of vehicles in cities. Thus, there is a requirement for smart traffic control methods for better accommodating the increasing demand. Therefore, the transportation system will continue to grow, and intelligent traffic controls have to be developed to face the road traffic problems. In this paper a comparison has been drawn for Neuro-Fuzzy (NF) based smart traffic control system and fuzzy logic based smart traffic control system. An adaptive neuro-fuzzy inference system is developed and tested against various traffic situations. Here we have trained the Adaptive Neuro-Fuzzy Inference System (ANFIS) system by various traffic situations so that ANFIS can draw the membership functions and corresponding rules by its own. Inputs which are generally used are Gap between two vehicles, last time vehicles that haven't passed during last green phase, delay at intersections, vehicle density, arrival rate, leaving rate and queue length. Arrival rate of the particular phase and last time vehicles that haven't passed during last green phase are taken as inputs to the system by the considering the practical applicability. Output of both the system are compared in terms of the average waiting time of the vehicles. ANFIS based traffic control system has been found more efficient as the average delay of the vehicle and the waiting time of the vehicles at the intersection have been reduced.

Keywords: -Traffic congestion; Neuro-Fuzzy (NF); ANFIS; Green Phase; Inflow rate; Last time vehicles

I. INTRODUCTION

The increase in urban traffic demand necessitates suitable approaches to manage traffic flow. Traffic lights are the most common approach to manage traffic flows on various types of intersections. Carefully co-ordinated signal timings can ensure smooth flow of traffic. Road traffic management is one of the main hurdles for almost all country which is in developing state. Due to urbanization the traffic problem is increasing year by year. Due to this congestion of traffic is also increasing. Some of the major harmful effects of high traffic congestion are: Increases in fuel consumption, Green house effect, creates environmental and health hazards.

A study of State road transport corporations of India shows that india is wasting a large amount of money and time due to traffic congestion every year. Developing country like india needs a better road traffic management and controlling of road traffic systems. So, it is very necessary to identify and thoroughly study the problem of traffic congestion, affordable and applicable fields of Intelligent Transportation System (ITS) technologies in the context of existing traffic condition and transportation system.

Although some different method of traffic control has been proposed and implemented by the passage of time. But none of them are efficient in terms of reducing the fluctuating traffic congestion. Recently in india some projects such as making flyover bridges, underpass, bullet train and metro rail had been taken to reduce the traffic Congestion problem. But these are costly and also time consuming projects. So we must develop an alternative way to solve this traffic congestion as quick as possible. One of the best alternative way could be applying the Adaptive Neuro-Fuzzy System (ANFIS) to our traffic controller which will be able to take real time data as inputs and based on the present traffic condition take intelligent decision.

In this paper an Adaptive Neuro-Fuzzy inference system (ANFIS) has been developed which can adapt itself with the changing inputs of traffic data. ANFIS has the advantage of both NeuralNetwork (NN) and Fuzzy systems. Here objective of ANFIS is to integrate the best features of Fuzzy Systems and Neural Networks. From Fuzzy Systems it takes ability of representation of prior knowledge into a set of constraints to reduce the optimization search space. And from Neural Networks it takes the ability of adaptation of back propagation to structured network to automate Fuzzy Control parametric tuning.

Trained ANFIS can draw the membership functions by its own and accordingly modify the rules associated with it. Trial and error method is used for training purpose in Fuzzy Logic which is a lengthy process and the output of the system is not accurate. But in Adaptive Neuro-Fuzzy inference system (ANFIS) training is done by Neural Network (NN) which uses less number of iteration than Fuzzy Logic.

II. FUZZY SYSTEM

Fuzzy controllers are being used in various control schemes. Following figure shows the basic building block diagram of a Fuzzy Logic Controller. In this block diagram there is major four blocks namely: fuzzificztion; Fuzzy decision making (Inference engine); knowledge base and defuzzification.

In fuzzy control input appilied to the fuzzification block..Fuzzification process converts the crisp value of inputs into the fuzzy value. After fuzzification fuzzy decision making block performs the necessary action based on the rule base and the membership functions. Membership functions are used to retranslate the fuzzy outputinto a crisp value. This method is known as Defuzzification. The fuzzy inference evaluates the control rules stored in thefuzzy rule base. Defuzzification is a process to convert the fuzzyoutput values of a fuzzy inference to real crisp values. In this system we obtain the intended output as the extension green time after defuzzification which is added to the particular phase based on the current traffic situations.
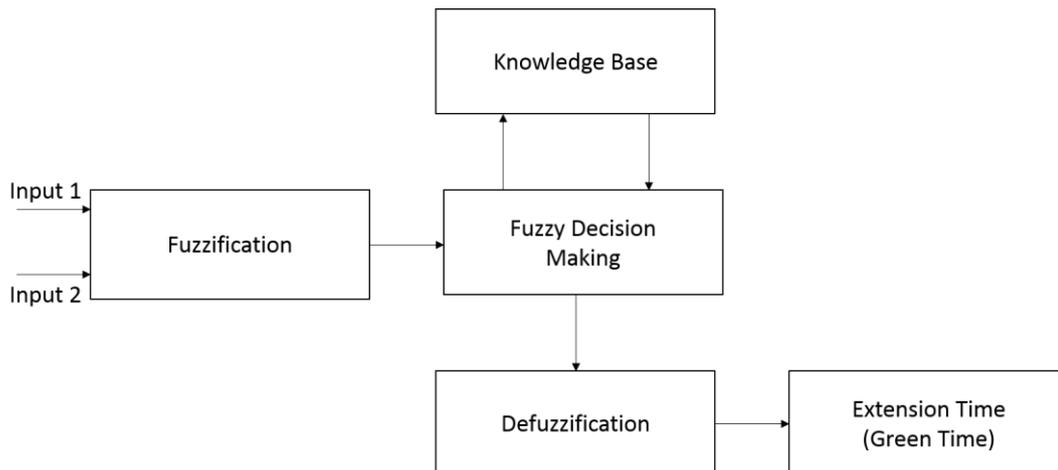

Figure. Building block diagram of a Fuzzy Logic Controller

III. ARCHITECTURE OF ANFIS (ADAPTIVE-NEURO-FUZZY INFERENCE SYSTEM)

Adaptive Neuro-Fuzzy Inference System (ANFIS) is one of the most successful and powerful schemes which combine the advantages of neural network and fuzzy system. An ANFIS works by applying neural learning rules to identify and tune the parameters and structure of a Fuzzy Inference System (FIS). There are several features of the ANFIS which enable it to achieve great success in a wide range of scientific applications. The attractive features of an ANFIS include: fast and accurate learning, easy to implement, excellent explanation facilities through fuzzy rules, and easy to incorporate both linguistic and numeric knowledge for problem solving strong generalization abilities.

The network can be regarded both as an adaptive fuzzy inference system with the capability of learning fuzzy rules and membership functions from data, and as a connectionist architecture provided with linguistic meaning. A typical architecture of an ANFIS is shown in fig, in which a circle represents a fixed node and square represents an adaptive node.

For a first-order Sugeno fuzzy model, a typical rule set with two fuzzy "if-then" rules can be expressed as follows:

Rule 1: If x is A1 and y is B1, then $f1 = p1 \, x + q1 \, y + r1$

Rule 2: If x is A2 and y is B2, then $f2 = p1 \, x + q2 \, y + r2$

Where x and y are the two crisp inputs, and Ai and Bi are the linguistic labels associated with the node function.

Input node (Layer 1): Layer 1 is known as the input layer. Nodes in this layer contains membership functions. Parameters in this layer are referred to as premise parameters. Every node nin this layer is adaptive node.

Node function is given by

$$O_n^1 = \mu_{A_n}(x) \text{For n= 1, 2}$$

Where x is the input to node n, and An is the linguistic label (small, large, etc.) associated with this node function.
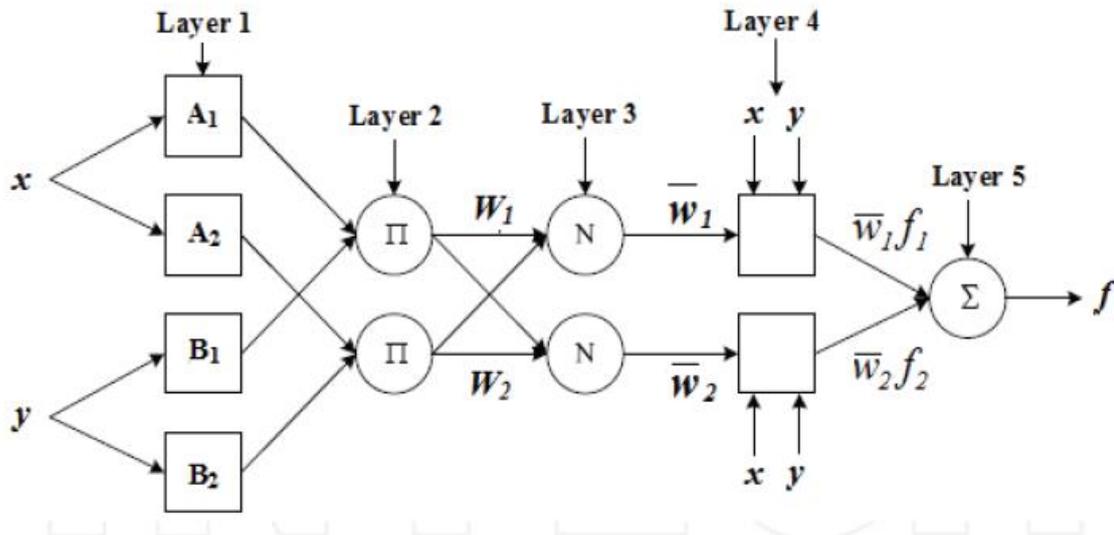
Figure. Architecture of ANFIS

Rule nodes (Layer 2): Every node in this layer is a fixed node labelled II. Output of this node represents a firing strength of a rule. Each node in this layer corresponds to a single Sugeno-type fuzzy rule. A rule neuron receives inputs from the respective input nodes and calculates the firing strength of the rule it represents.

$$O_n^2 = w_n = \mu_{A_n}(x)\mu_{B_n}(y) \text{For n= 1, 2}$$

Average nodes (Layer 3): Every node in this layer is a fixed node labelled N. The nth node calculates the ratio between the *n*th rule's firing strength to the sum of all rules firing strengths. Every node of these layers calculates the weight, which is normalized.

$$\overline{w_n} = \frac{w_n}{w_1 + w_2} \text{For n= 1, 2}$$

Consequent nodes (Layer 4): This layer includes linear functions, which are functions of the input signals. This means that the contribution of nth rules towards the total output or the model output and/or the function defined is calculated. Every node *n* in this layer is a adaptive node with a node function:

$$O_n^4 = \overline{w_n}f_n = \overline{w_n}(p_n x + q_n y + r_n)$$

Where $\overline{w_n}$ is the output of layer 3, and {pn, qn, rn} is the parameter set of this node. These parameters are referred to as consequent parameters.

Output node (Layer 5): The single node in this layer is a fixed node labelled Σ, which computes the overall output by summing all incoming signals.

$$O_n^5 = Overall\ Output = \sum_n \overline{w_n}f_n$$

IV. TRAFFIC LIGHTS CONTROL SYSTEM

In today's world, traffic lights control system uses two types of systems. Basically, there are two types of conventional traffic lights control system namely: fixed time and traffic actuated control methods. These control methods are used for controlling the isolated signalized intersections. Traffic actuated control method combines pre-set cycle time with proximity sensors which can activate a change in the cycle time or the lights.

In the case of a less travelled 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.

One type of control uses a pre-set cycle time to change the lights. 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 various inputs to the controller and allows a better assessment of changing traffic patterns. If traffic is more fluctuating then Adaptive neuro-fuzzy controller can be used instead of fuzzy logic controller. In this paper comparison of the both the controller is carried out in terms of the waiting time of the vehicles at the intersection as the performance parameter.
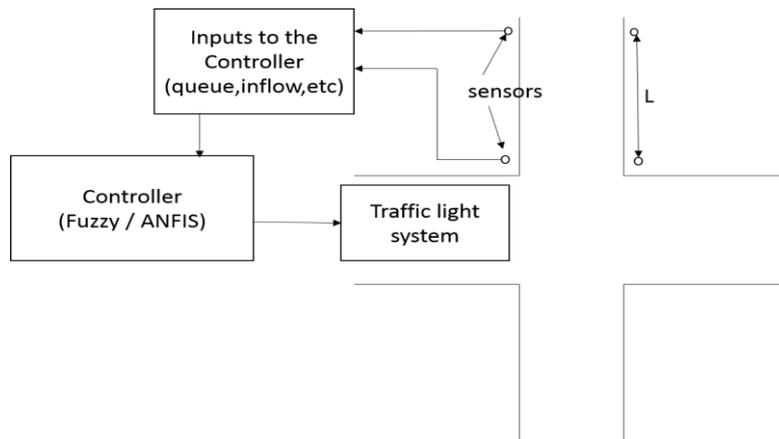

Figure 3. General structure of a traffic lights control system

The general structure of a traffic lights control system is illustrated as in Fig.1. There are two electromagnetic sensors placed on the road for each lane. The first sensor behind each traffic lights counts the number of cars passing the traffic lights, and the second sensor which is located behind the first sensor counts the number of cars coming to the intersection at distance L from the lights. The amount of cars between the traffic lights is determined by the difference of the reading between the two sensors. This is in contrast to conventional control systems which place a proximity sensor at the front of each traffic lights and can only sense the presence of a car waiting at the junction, not the amount of cars waiting at the traffic. The distance between the two sensors L, is determined accordingly following the traffic flow pattern at that particular intersection. The controller is responsible for controlling the length of the green time according to the traffic conditions.

For deciding inputs of the fuzzy inference system I had contacted traffic policeman of Vadodara city traffic police. So based on his expert knowledge about various traffic condition and traffic flow, I had derived rule base for the fuzzy inference system. Here I am not taking priority based system. In this controller fixed minimum green time of 5s is assigned to all four phases and then based on current traffic situation additional green time added as the extension green time. He suggested that if we take two inputs namely inflow rate and last time vehicles as the input to the system then it would be more beneficial.

Data given by him is as follow:

Number of vehicles passing through junction:-

High – 100 vehicles per minute

Medium – 50 to 60 vehicles per minute

Low- 10 to 20 vehicles per minute

Inputs of the fuzzy inference system are current inflow rate of vehicles at the junction for particular road and number of vehicles that haven't passed during last green signal.

Membership functions of inflow rates are

Very_high [80 95 110]

High [60 75 90]

Medium [40 55 70]
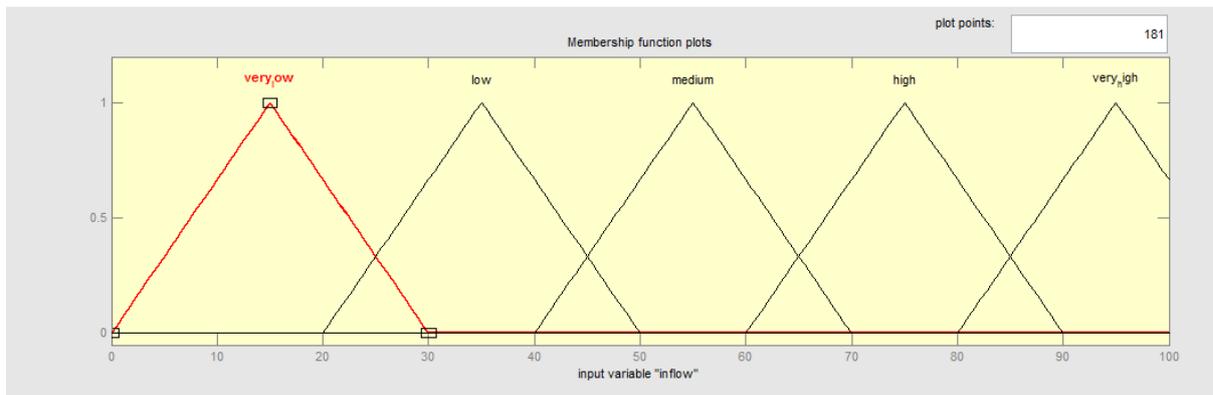
Low [20 35 50]

Very_low [0 15 30]

Figure 4. Input membership function of inflow rate

Membership functions of last time vehicles standing at junction are

Very_high [40 47.5 60]

High [30 37.5 45]

Medium [20 27.5 35]
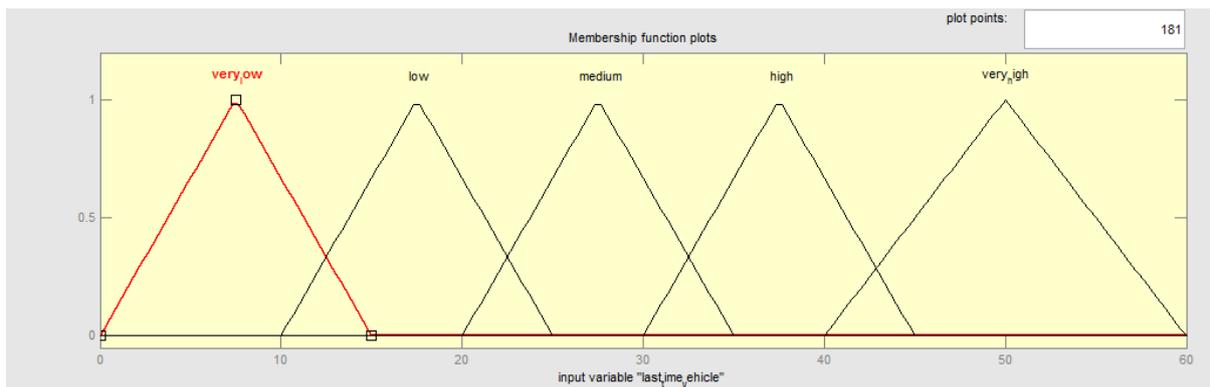
Low [10 17.5 25]

Very_low [0 7.5 15]

Figure 5. Input membership function of last time vehicles

Membership functions of output (green time extension) are

Very_high [40 47.5 55]

High [30 37.5 45]

Medium [20 27.5 35]
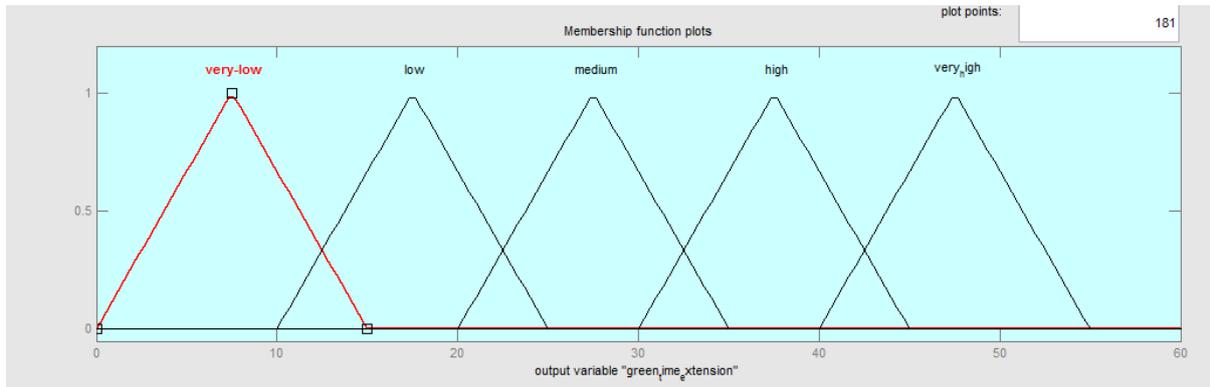
Low [10 17.5 25]

Very_low [0 7.5 15]

Figure 6. Membership function of output (green time extension)

Now for ANFIS controller either this fuzzy system is used for initial guess or based on training data ANFIS can derive its initial guess for the fuzzy system. I have developed training data for the adaptive neuro fuzzy inference system. It is an excel file in which all columns are inputs except the last column. Last column always used for the output. Waiting time of the vehicle at the intersection is equal to the sum of remaining red time of the current phase and red time of the other phases.

V. SIMULATION AND RESULTS

The above control strategies areimplemented using MATLAB tool. Comparison of the rule base of both control systems are given below. For the same inputs ANFIS controller has output equal to 24.5s and fuzzy controller has output equal to 27.5s. Left hand side figure shows the rule base for the ANFIS system and the other figure is for the fuzzy system.

Figure 7. Comparison of the rule base

Training result of ANFIS after 50 epochs for different methods is given in the below table:

No of epochs (50)	Error
Sugeno system	0
Grid partition method	4.0895e-06
Sub clustering method	1.05093e-08

Comparison of the surface view of both the systems is shown figure 8. We can clearly infer from the figure that the surface view is smoother in ANFIS controller. The transition of one rule to another is carried out smoothly in ANFIS controller. So no abrupt changes occur in the adjacent rules of the ANFIS controller. The surface view of the ANFIS controller is linearly distributed on both the axis. So, using ANFIS controller we have better results over the other control strategies which includes fuzzy logic controller, fixed time controller and traffic actuated controller.
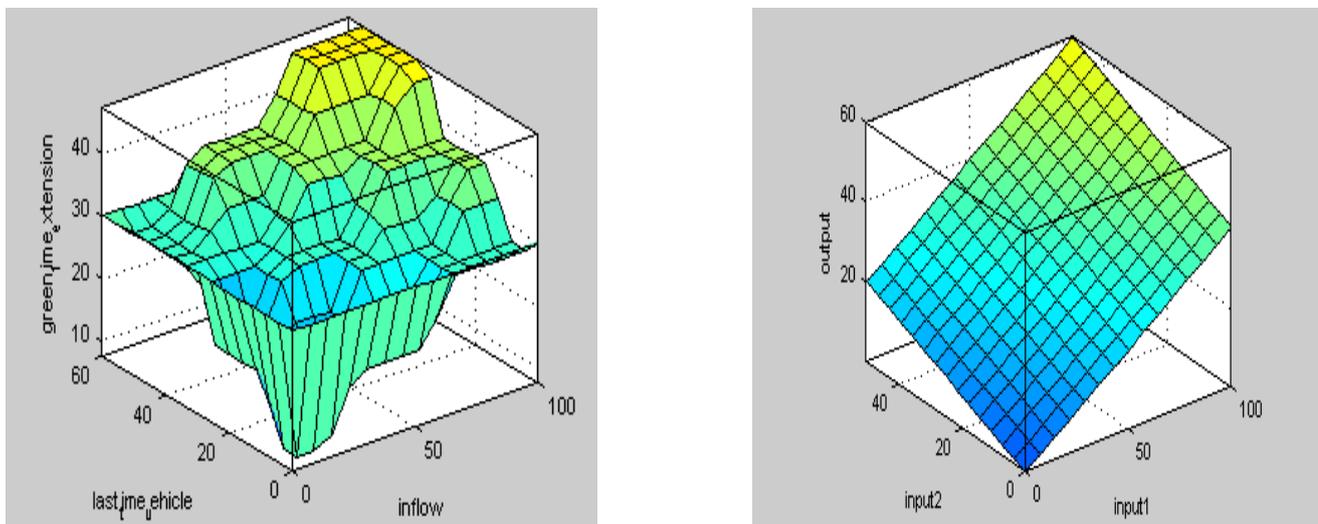

Figure 8. Comparison of the surface view

VI. CONCLUSION AND FUTURE WORK

In this paper, we are suggesting anANFIS based adaptive smart traffic lightcontrol system for an isolated 4-way intersection. ANFIS basedadaptive smart traffic light control system is able to control the fluctuatingtraffic in any intersection very efficiently and intelligently. TheAverage delay of the vehicles, Number of waiting vehicles has been calculatedfor the ANFIS, Fuzzy Logic and Fixed timing traffic control system. It hasbeen observed that the performance of the proposed system isbetter than the other two systems.An expansion of ANFIS based smart Traffic Light Controller for the group of intersections and the entire network can be planned.

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