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Fuzzy Logic Controller Based Traffic Light System

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Abstract- By the increasing use of automobiles in cities, traffic congestion occurs. And it is a major concern for many cities throughout the world. The effective solution to this issue would be to develop an optimized and sophisticated traffic monitoring control methods. In a conventional traffic light controller, the traffic lights change at constant cycle time. These automated systems do not provide an optimal control for fluctuating traffic volumes. A fuzzy logic based traffic light controller can be used for optimum control of fluctuating traffic volumes such as over saturated or unusual load conditions. The objective is to improve the vehicular throughput and minimize delays. Based on the Fuzzy Rules, the system decides, whether to extend the current green signal or terminate it. The control system also controls the continuous and safe flow of emergency vehicles. A prototype system for controlling traffic at an intersection is designed using VB6 and Matlab tool. The traffic intersection is simulated in VB6 and the data regarding the traffic parameters is collected in VB6 environment. The decision on the duration of the extension is taken using the Matlab tool. This decision is based on the Arrival and Queue of vehicles, which is imported in Matlab from VB6 environment. The time delay experienced by the vehicles using the fixed as well as fuzzy traffic controller is then compared to observe the effectiveness of the fuzzy traffic controller.

Keywords- Fuzzy Logic, Fuzzy Variables, Traffic Control, Membership Functions and Fuzzy Rule Base.

I. INTRODUCTION

As the number of vehicles and the needs for greater transportation has grown in recent years, city streets and highways frequently face serious road traffic congestion problems. Due to this factor, traffic signals now become a common feature of cities controlling heavy traffic. Careful planning of these signals is important to increase the efficiency of traffic flow on road. Controlling traffic on oversaturated intersections is a big issue. Main goals of traffic system are improving the traffic safety at the intersection, maximizing the capacity at the intersection and minimizing the delays. Thus careful design of traffic signal control would result in increasing the efficiency of the road network to yield economic and environmental benefits. Conventional methods for traffic signal control based precise models fail to deal efficiently with the complex and varying traffic situations. They are modelled based on the preset cycle time to change the signal without any analysis of traffic situation. Due to fixed cycle time, such systems do not consider that which intersection has more load of traffic, so should kept green more or should terminate earlier then complete cycle time. In case of intersections, conventional control systems only consider waiting time of signals on different directions but not the vehicle directions.

Fuzzy based controllers are proved to be well manager of traffic system in such scenarios. Fuzzy controllers have the ability to take decision even with incomplete information. More and more sophisticated controllers are being developed for traffic control. These algorithms are continually improving the safety and efficiency by reducing the waiting delay of vehicles on signals [1]. This increases the tempo of travel and thus makes signals more effective and traffic flow smooth.

The key motivation towards Fuzzy Logic in traffic signal control is the existence of uncertainties in signal control. Decisions are taken based on imprecise information and the effect of evaluation is not well known

The vehicle-actuated controller operates based on the traffic demand as registered by the actuation of vehicle. Here the length of the green phase is adjusted between minimum and maximum length depending upon the traffic flow. Minimum green time is the time for one vehicle to move through the intersection from the point of detection. The time for the phase to remain green is limited by maximum green time.

Controlling the timing of a traffic signal indicates a constant evaluation of the following: whether to (i) terminate the current phase and change to the next most appropriate phase or (ii) continue the current phase.

Thus the controller continuously or at regular intervals evaluates the status of each approach and takes the most appropriate decision. The process of controlling signal timings is difficult due to the following reasons:

- The process must be repeated within a short time interval.
- As the precise prediction of traffic condition in immediate future is not possible, the control action is based on optimizing the current status only. Thus the control action may not yield optimal condition in long term.
- The detectors cannot capture the details of the prevailing condition on the approach.
- Normally the optimization includes consideration of several simultaneous criteria like minimization of delays, queue lengths and percentage of stopped vehicles along with safety, which is an important parameter.

Hence in practice, traffic signal control should be based on the tailor -made solutions and adjustments, which would be made by the traffic planners. A traffic light controller based on fuzzy logic can be used as an optimum controller for fluctuating traffic volumes. The objective is to improve the throughput of the traffic and minimize delays.

Fuzzy logic controller allows linguistic and inexact traffic data to be manipulated in controlling the signal timings. The basic of fuzzy traffic signal controller is 'to model control strategy based on human expert knowledge rather than the modelling of the process itself.

Fuzzy logic technology allows the implementation of real-life rules similar to the way humans would think. In Traffic Control System, humans would think in the following way to control traffic situation at a certain junction: "if the traffic is heavier on the north or south lanes and the traffic on the west or east lanes is less, then the traffic lights should stay green longer for the north and south lanes". Such rules can now be easily accommodated in the fuzzy logic controller. In this consideration, we can say that it is replaceable to Traffic Police Officers. Fuzzy Logic works glowing when traffic flow in different directions is highly uneven as compared to Pre-timed Controller. A typical control system is shown in Figure 1.

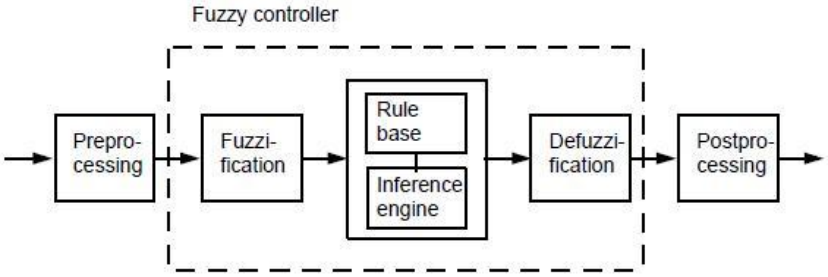

Figure 1: Fuzzy control system

II. FUZZY TRAFFIC SIGNAL CONTROL

In this paper, the implementation of fuzzy logic controller for the traffic flow control is discussed. Fuzzy logic technology has the capability of mimicking the human intelligence for controlling the traffic flow. It allows the implementation of real-life rules similar to the way in which humans would think. The theory of fuzzy logic is based on concepts graded to handle uncertainties and imprecision in a particular domain of knowledge. The graded concepts are useful since real situations in traffic control are very often not deterministic and cannot be described precisely.

Fuzzy logic allows linguistic and inexact data to be manipulated as a useful tool in designing signal timings. Also the linguistic control strategy that is decided by 'if-then-else' statements can be converted into a control algorithm using fuzzy logic. The design of a fuzzy signal controller needs an expert knowledge and experience of traffic control in formulating the linguistic protocol, which generates the control input to the traffic signal control system.

The aim of using fuzzy methods is attempt to model expert's thinking ion the situations where development of an exact mathematical model of the phenomenon is very difficult or even impossible. The main goals of fuzzy logic in the traffic signal control, and a matter of fact, also in traffic signal control in general, are

- Improving of traffic safety in the intersection.
- Maximizing the capacity of the intersection.
- Minimizing the delays.
- Clarifying the traffic environment.
- Influencing the route choices.

A fuzzy logic controller is designed for an isolated 4-lane traffic intersection as shown in the figure 2.

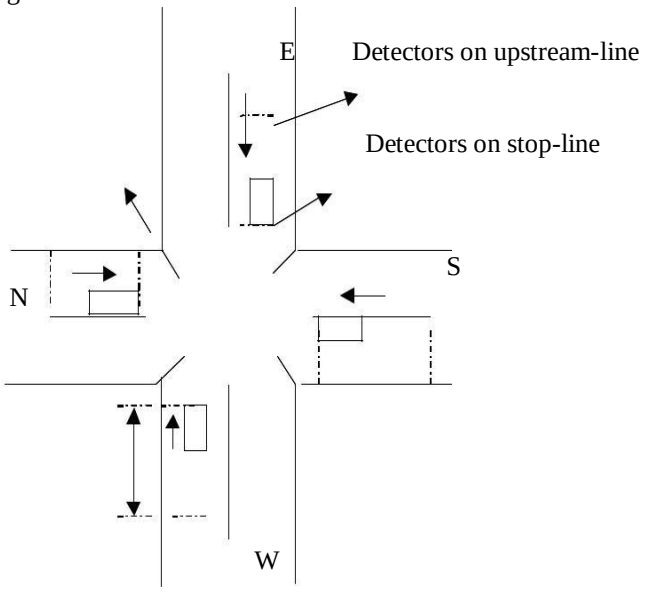

Figure 2: An intersection with detector configuration

III. METHODOLOGY

The fuzzy logic controller determines whether to extend or terminate the current green phase based on a set of fuzzy rules. The fuzzy rules compare traffic conditions with the current green phase and traffic conditions with the next candidate green phase. The flow diagram of a controller is shown in figure 3.

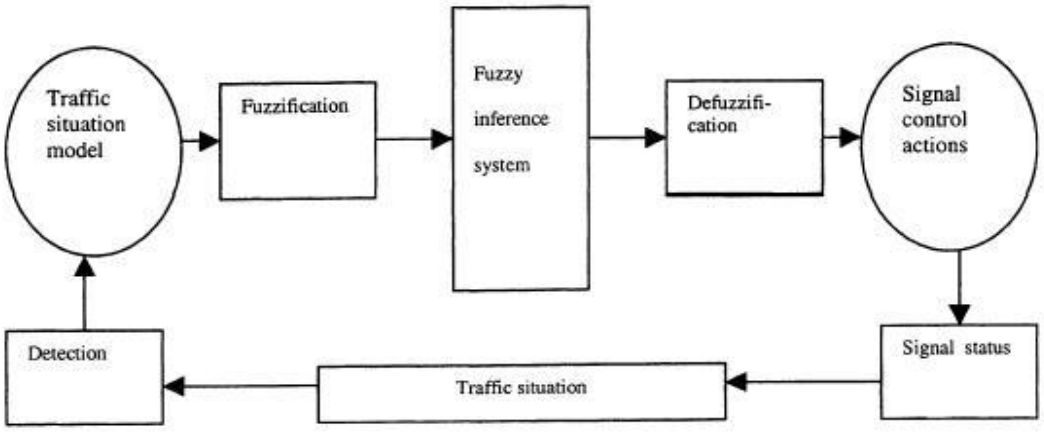

Figure 3: Fuzzy Traffic Signal Control

Cycle Time indicates the period to which current signal is green. If the cycle time is small, it denotes that it is usual time of green signal i.e. in normal situations; the cycle time of each signal is small. If traffic situation is such that it needs extension, then it can extend to long extension. If the cycle time is medium, it denotes that some extension has already been done, and now long extension cannot be done. If cycle time is already large then no extension is allowed, no matter what the situation of traffic. This is done to avoid starvation of any signal. In case of large cycle time, short extension is allowed only when emergency vehicle is in the current green signal.

Controlling of emergency vehicle is done by investigating their presence. If the emergency vehicle is in the current green signal then extend the signal for short extension only. When there is a situation, emergency vehicles are both in current signal and any other signal then extend the current signal. If emergency vehicle is in any signal which is not green then terminate the current signal.

IV. FUZZY PARAMETERS AND THEIR MEMBERSHIP FUNCTIONS

The set of control parameters is:

EV = Emergency Vehicle
CT = Cycle Time of Current Green Signal
Q_C = Queue Length of Current Green Signal
Q_N = Queue Length of Next Signal to be Green
AR_C = Arrival Rate of Current Green Signal
AR_N = Arrival Rate of Next Signal to be Green CS=Current Signal
NS = Next Signal

Table 1: Input & Output Variables and Their Membership Functions

Input Variables			
EV	**CT**	**Q_C/Q_N**	**AR_C/AR_N**
Present Not Present	Small Medium Large	V Low Low Medium High V High	Low Medium High
Output Variable			
Extension		Zero Short Medium Large	

V. FUZZY RULE SET

The fuzzy controller decides an extension of current green signal on the basis of rules set. These rules will act differently on the basis of Cycle Time. As mentioned earlier, by default, the cycle time is 'Small' for every signal. Extension from small CT will be on certain rules. 'Small' CT will allow extension to 'Long'. If the cycle time is 'Medium', it shows, it already had some extension, so that signal can extend only to 'Medium'. In case of already 'Large' cycle time, the extension will be given only in the presence of Emergency Vehicle. When Emergency vehicle is there on any signal then it will ignore all other traffic factors and extension will be given to that signal.

Some of the rules are shown below:

1. If EV in CS is present then Short extend.
2. If EV in NS is present then Zero extend.

   If CT is 'Medium' then extension can be 'Zero', 'Short' or 'Medium'. No Long extension.
3. Q_C is V Low and AR_C is low then Zero extend.
4. Q_C is Medium and AR_C is Low and Q_N is Medium and AR_N is High then Zero extend.
5. Q_C is V High and AR_N is Low and Q_N is Low then Medium extend.

   If CT is 'Small' then all values from extension set are possible i.e. extension can be done to 'Long'.
6. Q_C is V Low and AR_C is Medium and Q_N is V Low then Short extend.
7. Q_C is L Low and AR_C is High and AR_N is Low and Q_N is V low then Long extend.
8. Q_C is High and AR_C is Low and Q_N is V High then Zero extend.
9. QC is V High and ARC is High and QN is Medium then Long extend.
10. Q_C is V High and Q_N is V Low then Long extend.

VI. SIMULATION OF THE TRAFFIC AT AN ISOLATED INTERSECTION

A signalized intersection with 4 approaches and typical vehicle detectors is considered as shown in fig 1. Vehicle detectors are installed on 'upstream-line' and 'stop-line'. The number of approaching vehicles for each approach during given time interval can be estimated using the detectors. Fuzzy variables considered are arriving vehicles (A), queuing vehicles (Q) and extension (EXT).

The membership functions for the arriving vehicles (A) at the approach having green phase are few = -4 to 4, small = 0 to 8, medium = 4 to 12 and many = 8 to 16.

The membership functions for the queuing vehicles (Q) at the next approach having red phase are few = -4 to 4, small = 0 to 8, medium = 4 to 12 and many = 8 to 16.

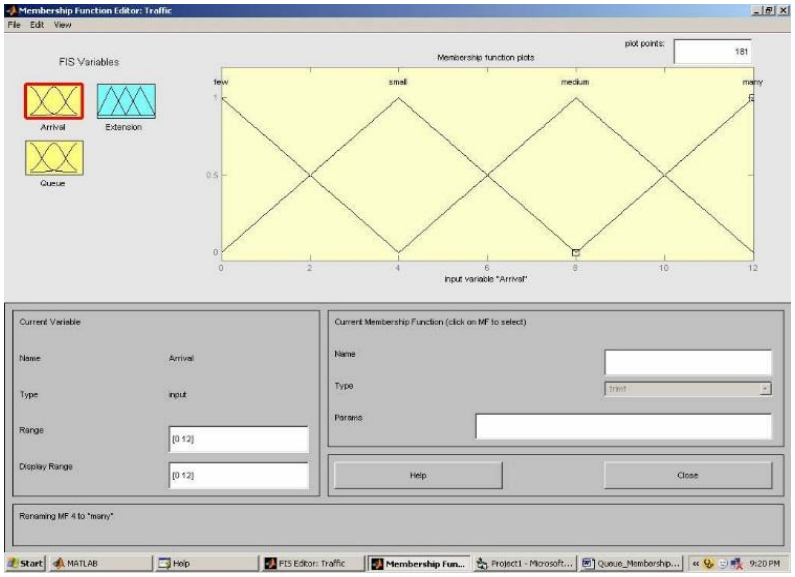

Figure 4: Input Fuzzy Variable 1-Arrival

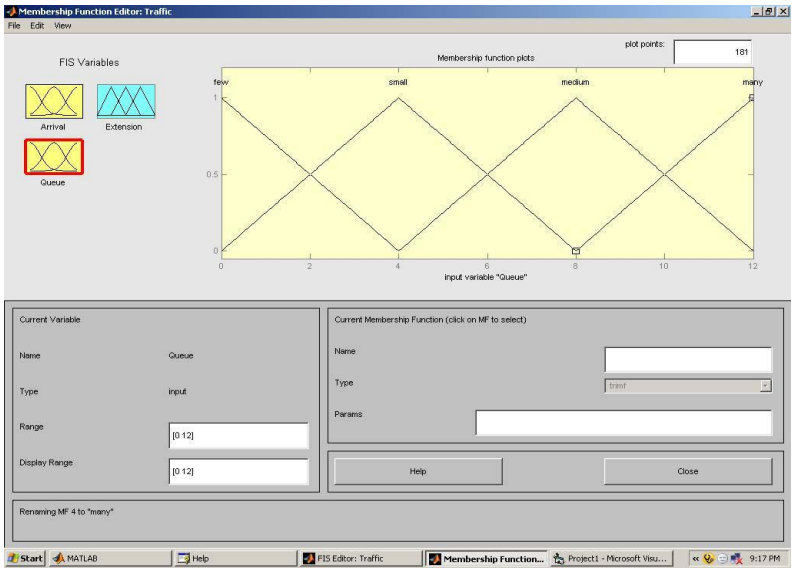

Figure 5: Input Fuzzy Variable 2-Queue

Based on the input fuzzy parameters the duration of the output variable 'Extension' is determined. The membership functions for the output fuzzy variable extension (EXT) are: zero = 0 to 5 sec, short = 5 to 10 sec, medium = 10 to 15 sec and long = 15 to 20 sec. Following fuzzy rule-base is proposed for the extension or termination of current green phase.

The fuzzy logic controller determines whether to extend or terminate the current green phase after a minimum green time has been elapsed. If the green time is extended, the fuzzy logic controller will determine whether to extend the green after the time interval Δt. In this paper, the time interval Δt is taken as 5 sec.

A) Fuzzy Rule Base

After a minimum green (5 s)

If Arrival is few AND Queue is (few OR small OR medium OR many) then Extension is zero.
Else if Arrival is small AND Queue is (few OR small) then Extension is short.
Else if Arrival is small AND Queue is (medium OR many) then Extension is zero.
Else if Arrival is medium AND Queue is (few OR small) then Extension is medium.
Else if Arrival is medium AND Queue is (medium OR many) then Extension is short.
Else if Arrival is many AND Queue is few then Extension is long.
Else if Arrival is many AND Queue is (small OR medium) then Extension is medium.
Else if Arrival is few AND Queue is many then Extension is short.

After the first extension i.e. (ext1 + min. green of 5 s) If Arrival is few AND Queue is (few OR small OR medium OR many) then Extension is zero.
Else if Arrival is small AND Queue is (few OR small) then
Extension is zero.
Else if Arrival is small AND Queue is (medium OR many) then Extension is zero.
Else if Arrival is medium AND Queue is (few OR small) then Extension is short.
Else if Arrival is medium AND Queue is (medium OR many) then Extension is zero.
Else if Arrival is many AND Queue is few then Extension is medium.
Else if Arrival is many AND Queue is (small OR medium) then Extension is short.
Else if Arrival is few AND Queue is many then Extension is zero.

After the second extension, no extension shall be given to the current green phase. After the second extension, the most suitable next green phase is selected using phase sequencing rule-base. The main aim is to maximize the capacity of the signalized intersection by minimizing the inter green times.

Weight, W (A) of an approach is derived from the number of queuing vehicles waiting for the green signal in each red phase. Linguistic labels for W (A) are zero (Z) = -4 to 4, low (L) = 0 to 8, medium (M) = 4 to 12 and high (H) = 8 to 16.

The rules are formulated to give priority to that approach with the highest demand for green time.

It is assumed that initially the approach 'N' is given the 'right of the way' i.e. green signal is given to the vehicles travelling towards 'north'.

W(E), W(W), W(S) and W(N) denote the weights associated with 'east', 'west', 'south' and 'north' approaches respectively.

After the extensions, the next approach, which avails the green phase, is given by following fuzzy rule-base.

If W (W) is high then next green phase is W
Else if W (W) is medium and W (S) and W (E) is low then next phase is W
Else if W (W) and W (S) and W (E) is low then next phase is W
Else if W (W) is less than high and W(S) is high and W (E) is any then next phase is S
Else if W (W) is low and W (S) is medium and W(E) is less than high then next phase is S
Else if W (W) is less than high and W (S) is less than high and W (E) is high then next phase is E
Else if W (W) and W (S) is low and W (E) is medium then next phase is E.

VII. RESULT

A basic fuzzy logic control algorithm for full intersections and left and right turn lanes was developed. The fuzzy logic controller makes the decision to what extent the current green phase has to be extended based on a set of fuzzy rules and real-time traffic information.

A large number of improvements are planned for the future; they include the following:

- Additional simulation tests on intersections with different levels of geometric complexity, phasing and demand.
- The cycle time may be further fuzzified to get better results.
- Expansion of the fuzzy logic controller strategy to arterial and network applications.

The above two algorithms of fuzzy rule base are implemented using MATLAB tool. An isolated Traffic Intersection is simulated in Visual Basic 6 environment. Sample screen shot for the same is as attached herewith.

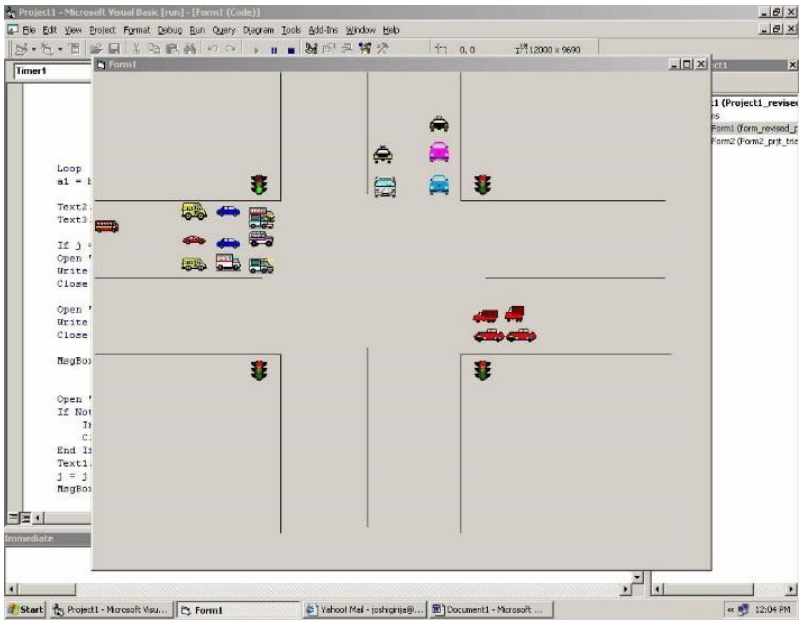

Figure 6: Simulated Traffic Intersection

Following graph shows the comparison of the number of waiting vehicles at an approach for both fuzzy as well as fixed traffic controller. From the graph it is observed that the fuzzy controller is more effective than fixed controller.

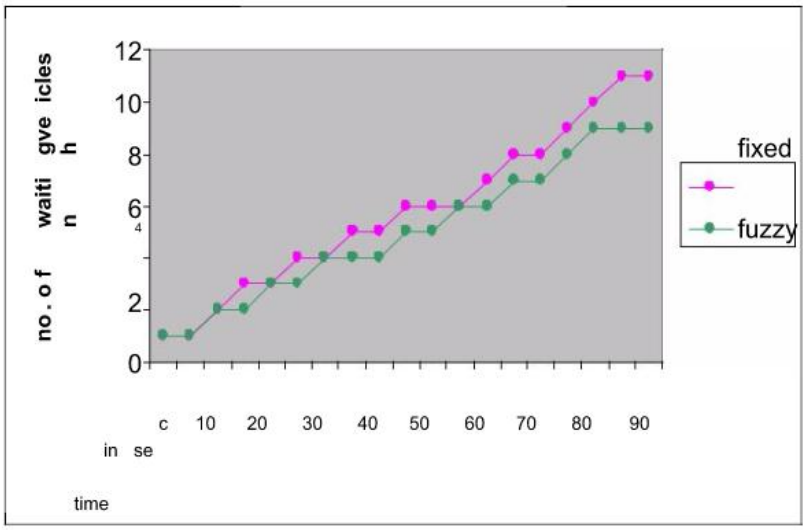

Figure 7: Graph comparing performance of Fixed and Fuzzy Controller

VIII. FUTURE WORK

An expansion of Fuzzy Traffic Light Controller for the arterials and the entire network can be planned. Also the use of Fuzzy Traffic Light Controller can be used to control pedestrian traffic control along with vehicular control.

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