Simulation of Adaptive Traffic Signal Controller in MATLAB Simulink Based On Fuzzy Inference System

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ABSRACT

This paper presents a Simulation of Fuzzy Traffic Controller design for controlling Green Light time for effective traffic flow. Intelligent Traffic controllers are required these days to adjust to a situation of ever increasing traffic. Artificial Intelligence technique such as neuro-fuzzy systems, fixed time embedded controllers, etc. are available to handle the traffic related problems. But Adaptive traffic signal controller based on Fuzzy Inference System used in this project provides smart solutions for efficient traffic control. This system reflects two fundamental aspects of traffic responsive signal control- the observation of on-going traffic situation around the intersection, and the control of the traffic signals in a manner appropriate to the observed situation. In traffic signal control system, detection of traffic variables at intersection is very important and is the basic input data to determine signal timing. The controller is developed based on traffic density and traffic flow rate. This FIS module is developed in SIMULINK environment of MATLB tool which has achieved the satisfactory results for traffic signal control. The "Adaptive Traffic Signal Controller based on Fuzzy Inference system" is capable of taking decision to reduce delays at intersection.

Keywords

Fuzzy, Inference System, Intelligent, Delays at Intersection, Simulink, Density, Flow rate.

1. INTRODUCTION

Traffic signal is an essential element to manage the transportation network. At present, a major research focus has been on application of artificial intelligent techniques, for example, expert systems, fuzzy logic. To improve traffic flow and safety of the current transportation system is to apply automation and intelligent control methods to roadside infrastructure and Vehicles. The complexity of modern traffic control system makes their design & optimization a complex task. Nevertheless, well configured traffic systems are essential to avoid unnecessary congestion in traffic network and to reduce the negative economic and environment impact of traffic.

Various computational intelligence based approaches have been proposed for designing real time traffic signal controllers, such as fuzzy sets, genetic algorithm and reinforcement learning and neural networks (NN). The Fuzzy logic theory is introduced in the traffic controller to provide an intelligent green interval response based on dynamic traffic load inputs. A fuzzy logic control scheme is proposed to overcome the inefficiency of conventional traffic controllers that has a preset cycle time regardless of dynamic traffic load. This system brings fuzzy logic into toolbox currently available to traffic planners and engineers, enhancing their ability to deal with urban congestion problems so prevalent.

Modern approaches towards designing traffic signal controllers suggest way to convert loop detector data or video detector into no. of vehicles waiting for queue for a major arterial intersection under interrupted traffic flow conditions by means of fuzzy logic and neural networks.

The fuzzy controller can be used with the input variables of the weighted traffic flow at the current and neighbouring intersections. This can be helpful for reducing the complexity of controllers. i.e., the controller has less input variables.

2. DESIGN OBJECTIVES

Intelligent traffic control system is generally designed for different traffic parameters. The important parameters which contributes most for all types of traffic like homogeneous and heterogeneous in urban, rural and metro cities are

2.1 Congestion at the intersection

The type and intensity of congestion depends on many quantifiable factors such as volume, speed, headway, ratio of slow moving and fast moving vehicles etc. In this context, the quantification and evaluation of congestion severity has been taken as an important research to give a modification to the generalized design procedures and also to suggest the remedial solutions for releasing congestion. With increasing number of vehicles on road, heavy traffic congestion has substantially increased in major cities. The main effect of this matter is increased time wasting of the people on the road. The solution for this problem is by developing the program which different setting delays for different junctions. The delay for junctions that have high volume of traffic should be setting longer than the delay for the junction that has low of traffic.

2.2 Delay in traffic

There are many metrics exist in order to evaluate the performance of a traffic light controller. One of the most important metric to optimize, as it impacts directly on drivers is called the delay. The delay is defined by the amount of additional time a vehicle takes to complete its journey through the network because of traffic lights. Another interesting metric is the throughput which gives the number of vehicles that cross the intersection in a specified amount of time. Clearly, the general optimization goal for traffic network designers is to lower the delay and to increase the throughput of vehicles.

2.3 Queue Length

Queue length for particular lane increases due to ineffective traffic signal controller which leads to traffic problems like congestion. To resolve this problem, it would be more feasible and sensible to pass more vehicles at green interval. This will overcome the weakness of conventional traffic controllers with the capability of providing with varying green time cycle interval based on dynamic traffic load changes at every lane in a 4 way junction control.

2.4 Selection of Inputs for Fuzzy Traffic Controller

To improve the efficiency of the traffic signal controller, it becomes very important to select the input parameters for fuzzy traffic signal controller. In this paper for effective traffic control, traffic density and traffic flow rate are used as inputs to the system.

Traffic density is defined as the number of vehicles per unit length standing at the intersection. Here, in this paper, density is calculated for homogeneous vehicles only. These vehicles are detected by the two sensors applied at the intersection. One sensor is placed at front of the queue length of the vehicles and other is placed at back of the queue length of vehicles. The unit of traffic density is vehicles/Km. Thus density of the vehicles is calculated as

Density= (No. of Vehicles) / (Length between two sensors).

Traffic flow rate is defined as the number of vehicles passing through the intersection in per unit time. The unit of Traffic flow rate is Vehicles/Hr.

3. DESIGN OF FUZZY TRAFFIC CONTROLLER

This fuzzy traffic controller is designed in Mamdani-Type Fuzzy Inference System in MATLAB Toolbox. Mamdani –Type Fuzzy Inference system consists of three phases: Fuzzification, Rulebase and Defuzzification.

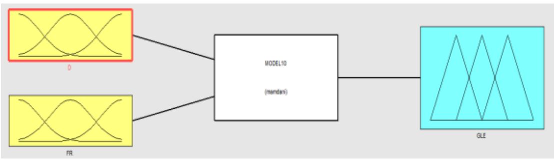

Figure 1. Basic Structure of FIS

3.1 Fuzzification

There are several types of membership functions available for designing the input characteristics of the input. Since inputs applied to the system i.e. Traffic Density and Traffic Flow Rate vary linearly with time, triangular shaped membership function are used for both the inputs.

The Traffic Density (D) of vehicles is assumed to be ranged from 0 to 100 Vehicles/km. The input membership function of Traffic Density, D, is divided into five ranges: Very Small (VSD), Small (SD), Large (LD), Very Large (VLD) and Extremely Large (ELD). Here, concept of overlapping membership function is used to identify each value of density for corresponding membership function.

The ranges of VSD, SD, LD, VLD and ELD are 0 to 40Veh/KM, 20 to 60Veh/KM, 40 to 80Veh/KM, 60 to 100Veh/KM and 80 to 100Veh/KM respectively.

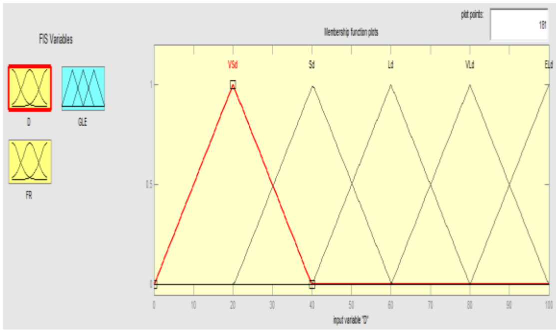

Figure 2. Input Membership Functions For Traffic Density (Input1)

The Traffic Flow Rate (FR) of vehicles is assumed to be ranged from 0 to 1000 Vehicles/Hr. The input membership function of Traffic Flow Rate, FR, is divided into five ranges: Very Small (VSFR), Small (SFR), Large(LFR), Very Large (VLFR) and Extremely Large (ELFR). The ranges of VSFR, SFR, LFR, VLFR and ELFR are 0 to 400Veh/HR, 200 to 600Veh/HR, 400 to 800Veh/HR, 600 to 1000Veh/HR and 800 to 1000Veh/HR respectively.

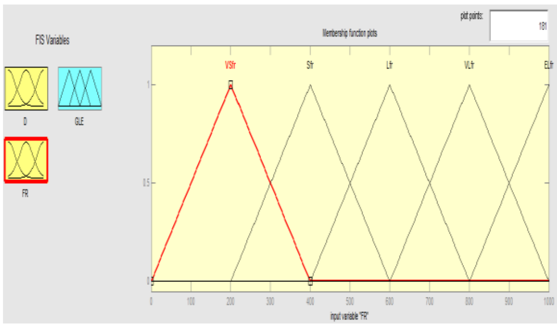

Figure 3. Input Membership Functions For Traffic Flow Rate (Input2)

The output of Fuzzy inference system is Green Light Extension Time which ranges from 0 to 100 seconds. The output membership function of Green Light Extension, GLE, is divided into five ranges: Very Small (VS), Small (S), Large (L), Very Large (VL) and Extremely Large (EL). The ranges of VS, S, L, VL and

EL are 0 to 40 Sec, 20 to 60 Sec, 40 to 80Sec, 60 to 100 Sec and 80 to 120 Sec. respectively.

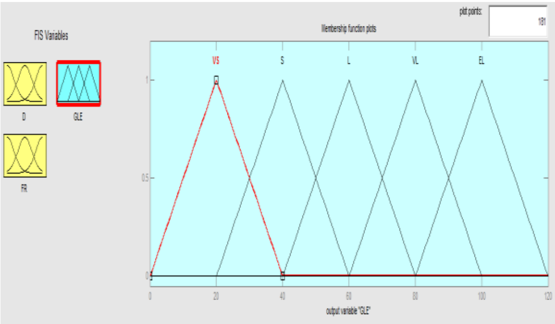

Figure 4. Input Membership Functions For Green Light Time Extension.

3.2 Rulebase

Fuzzy linguistic description are formal representation of systems made through fuzzy IF-THEN rules. For this particular fuzzy inference system used in the project, 13 possible rules have been developed for effective implementation of Fuzzy Traffic Controller.

Table 1. Fuzzy Rules

Rules	Input1(D)	Input2(FR)	Output(GLE)
1	VS	VS	VS
2	VS	S	VS
3	S	VS	S
4	S	S	S
5	S	L	L
6	L	S	L
7	L	L	L
8	L	VL	VL
9	VL	L	VL
10	VL	VL	VL
11	VL	EL	EL
12	EL	VL	EL
13	EL	EL	EL
14	VS	NONE	VS
15	S	NONE	S
16	L	NONE	L
17	VL	NONE	VL
18	EL	NONE	EL
19	NONE	VS	VS
20	NONE	S	S
21	NONE	L	L
22	NONE	VL	VL
23	NONE	EL	EL

3.3 Defuzzification

The conversion of fuzzy set to a single crisp value is called defuzzification. Several methods are available for defuzzification methods like Centroid method, Centre of Sum method, Mean of Maxima method. In this project Centroid method of defuzzification is used. In this centroids are computed for each of the competing output membership functions. Then the new output membership areas are determined by shortening the height of the membership value on Y axis as directed by the rule strength value. Finally, the Centre of Gravity (CG) is computed using the weighted average of X-axis Centroid points with the newly computed output areas, the latter serving as weights.

4. FUZZY TRAFFIC CONTROL ALGORITHM

This algorithm is developed for 4 way intersection having homogeneous traffic. The coordination of traffic flow is executed in orderly fashion. Four constant values of traffic density and traffic flow rate of four lanes are sensed by infrared sensors fixed at road intersection and along the length of each road. Among these four values, only one value of density and flow rate are selected for applying to input of Fuzzy Inference System. This FIS system defuzzifies the values, gives fuzzified output according to rules written in the rulebase of FIS system and provides the defuzzified output which is a single crisp value of Green Light Extension Time.

Fuzzy Logic Controller block in simulink model accepts only name of FIS system developed in MATLAB with .fis extension.

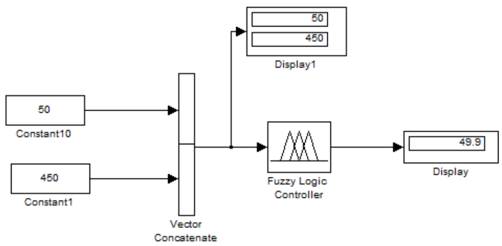

Figure 6. SIMULINK Block Diagram of Showing Inputs and Output For Fuzzy Logic Controller

FIS system takes two values (density and flow rate) applied through vector concatenate block. Display1 showing input values of density (50 Veh/Km) and flow rate (450 Veh/ Hr) applied to FIS system. The output value 49.9 seconds is calculated by decision taking device i. e. Fuzzy controller according to rules written in rulebase of FIS Ststem. This is the crisp value of time for which Fuzzy traffic signal controller provides green light extension for lane whose density and flow rate values are provided as inputs.

```
While (p<=4)
 n=GLE;
 p=p+1;
while ((p==1) && (n>=5))
g1=1; r1=0; y1=0; g2=0; r2=1; y2=0; g3=0; r3=1; y3=0;
g4=0; r4=1; y4=0;
n=n-1;
pause (1);
```

Figure 7. Program code in "Embedded Matlab Function block" to keep the green light ON of current lane for time calculated by the FIS system.

```
While ((p==1) && (n>0))
g1=0; r1=0; y1=1; g2=0; r2=1; y2=0; g3=0; r3=1; y3=0;
g4=0; r4=1; y4=0;
pause  (1)
n=n-1;
if (n==1)
a=2;
```

```
end;
```

Figure 8. Program code in "Embedded Matlab Function block" to keep yellow light ON of current lane for 5 seconds.

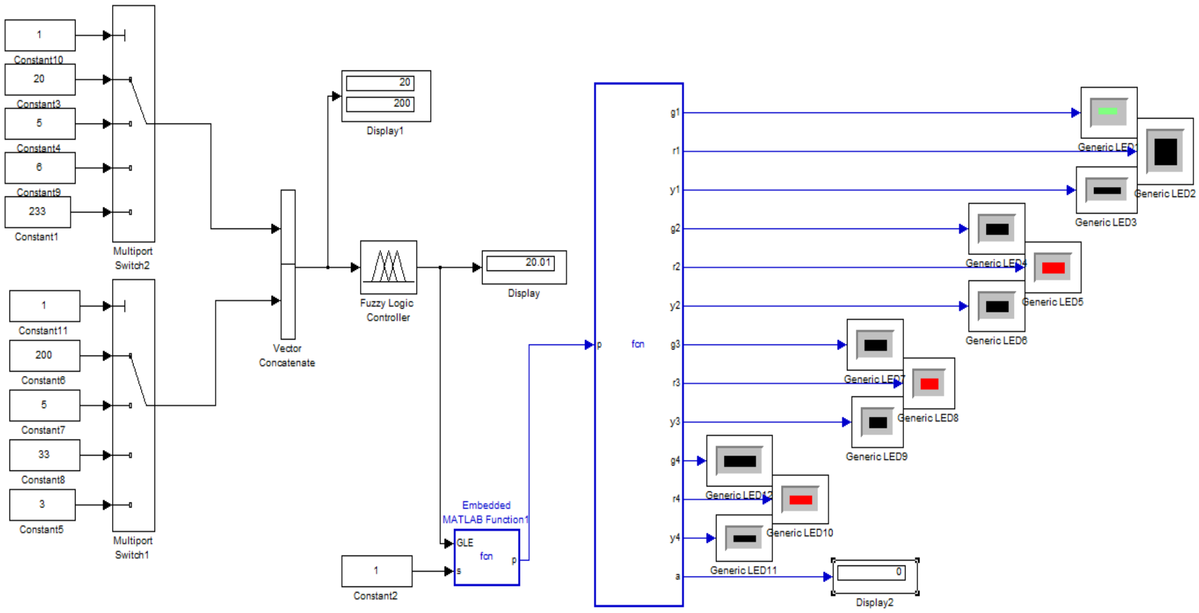

Figure 5. SIMULINK Block Diagram of Fuzzy Traffic Signal Controller.

5. SIMULATION RESULTS AND DISCUSSIONS

Simulation of this fuzzy traffic controller is made in SIMULINK environment of MATLAB. Results for green light extension time in seconds are obtained with SIMULINK model of fuzzy traffic controller which shows linear increment in the green light extension time for increasing values of traffic density and traffic flow rate. When traffic density (0-100 Veh/Km) and traffic flow rate (0-1000 Veh/Hr) is varied within their full range, green light time also varies within its full scale (0-100 seconds).

At constant value of traffic flow rate, green light extension time increases slowly with respect to traffic density. When density is kept constant and arrival (i.e. traffic flow rate) is increased slowly, the green light extension time also increases. However, when traffic flow rate become comparable or higher than traffic density, the green light extension time tends to increase, allowing higher number of vehicles to pass the junction.

This simulation results shows linearity between inputs applied to the Fuzzy Inference System and output drawn from it. These results are satisfactory for achieving the objectives decided in this project.

6. CONLUSION

The Adaptive Traffic Signal Controller based on Fuzzy Inference System is developed which provides satisfactory results for allotting changing green light time for dynamic traffic. This solution is helpful for achieving objectives decided in this project. Fuzzy logic is a powerful and User-friendly tool for dealing with the complex problems of traffic responsive signal control in a straight forward and intuitive way without losing any of the desired features of the problem solution. Adaptive neuro-fuzzy controller provides number of advantages starting from its implementation since it requires only a set of input values and modeled output values to decide the optimum membership functions and rules by it.

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