

Use of Fuzzy Logic in Traffic Congestion Management

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Abstract— In many large cities across the world, traffic congestion is a major issue. A nation's economy may be impacted by traffic congestion, which can also raise costs, impede development, and worsen environmental pollution. This study deals with the development of fuzzy logic-based traffic signal which has dynamic cycle length. Fuzzy logic is the foundation for the development of this kind of traffic signal. The traffic signal control system accounts for the uncertainty and ambiguity of information regarding the input and output parameter values. Fuzzy logic adeptly manages this form of ambiguity and uncertainty. Traffic density and traffic flow are the input factors used in fuzzy logic-based traffic signal control. To determine the cycle length, the fuzzy traffic signal controller applies the input parameters to a fuzzy inference system. The Mamdani inference mechanism is utilized in fuzzy logic systems. Vehicle wait times at intersections are reduced by adjusting the traffic signal's cycle length based on traffic conditions.

Keywords— Cycle Length, Fixed Time Traffic Signal Control, Fuzzy Logic, Inference System, Webster's formula.

Introduction

In many large cities across the world, traffic congestion is a major issue. A nation's economy may be impacted by traffic congestion, which can also raise costs, impede development, and worsen environmental pollution. This study deals with the development of fuzzy logic-based traffic signal which has dynamic cycle length. Fuzzy logic is the foundation for the development of this kind of traffic signal. The traffic signal control system accounts for the uncertainty and ambiguity of information regarding the input and output parameter values. Fuzzy logic adeptly manages this form of ambiguity and uncertainty. Traffic density and traffic flow are the input factors used in fuzzy logic-based traffic signal control. To determine the cycle length, the fuzzy traffic signal controller applies the input parameters to a fuzzy inference system. The Mamdani inference mechanism is utilized in fuzzy logic systems. Vehicle wait times at intersections are reduced by adjusting the traffic signal's cycle length based on traffic conditions.

Conventional traffic signal controllers repeat the same predetermined signal timing based on past traffic patterns. The University of California, Berkeley originally created fuzzy logic in 1960. The foundation of fuzzy set theory is data ambiguity, vagueness, and uncertainty. A mathematical method for simulating how people formulate

and reason is called fuzzy logic. The fuzzy logic-based traffic signal was developed with the intention of creating a signal control system based on human expert knowledge. Fuzzy logic may mimic verbal instructions. Fuzzy logic is a great way to deal with the kind of data that is typically confusing and unpredictable when it comes to traffic at signalized intersections. Fuzzy logic is therefore a viable method for simulating traffic signal regulation, which is predicated on subjectivity, ambiguity, and imprecision. Fuzzy logic controllers can be used to manipulate linguistic and imprecise traffic data to control signal timings.

The objectives of Fuzzy Logic in Traffic Congestion Management.

1. To apply fuzzy logic as a traffic signal control technique.
2. To analyse fuzzy logic-based traffic signal control conceptually
3. To develop fuzzy rules for traffic signal control using human understanding.

Literature Review

Gokulan BP, Srinivasan D.2010[1] For traffic signal control, a multi-agent technique was used. This geometric fuzzy multi-agent system was employed. The geometric type-2 fuzzy inference system was employed in this system. This inference system works effectively for managing uncertainty in the input variables and rule basis. The outcomes are compared with the current traffic signal control system.

Balaji PG, Srinivasan D.2010[2] A type-2 fuzzy system is also suggested; in this system, the weights for the input data gathered from the road network are computed, and the green light period is determined based on this input.

Qiao F, Yi P, Yang H, 2002[3] For an isolated four-way intersection, a two-stage fuzzy logic traffic signal controller was created. This controller outperformed the vehicle-actuated traffic signal control, according to the simulation results.

Saeed Y, Khan MS, Ahmed K, Mubashar AS 2011[4] An autonomous and multi-agent traffic signal control system based on fuzzy logic was suggested.

Akramizadeh A, Afshar A, 2006[5] In an urban traffic problem, a traffic controller based on fuzzy logic is used. The

three primary components of this controller are dispersed problems, human behavior participation, and time changes on the intersections. Based on these elements' fuzzy logic-based Traffic Congestion Management using traffic signal control is developed.

Control of Fixed-Time Traffic Signals

The fixed time traffic signal control modifies the signals based on a predetermined cycle and green light time. In India the cycle length of traffic signals is calculated using two methods, a) Trial Cycle Method (Iterative Approach), b) Webster's formula. The cycle length according to the Indian highway capacity manual is calculated by,

$$C = (1.5L + 5) / (1.0 - Y)$$

L = total lost time per cycle

Y = the sum of critical lane volume to saturation flow ratios.

The saturation flow rate in this case is 1950 cars per hour.

L = (no. of phases) * lost time per phase + all red time,

L = 10 seconds.

The entire time it takes for drivers to react and accelerate is known as lost time. The period during which all signals turn red following each yellow is known as the "all red time," and it is used to empty the junction of cars.

Fuzzy Logic in Traffic Congestion Management

fuzzy logic-based Traffic Congestion Management using traffic signal control the sensors are assigned to the intersection road for a specific length of road in the fuzzy logic-based traffic signal control system. These sensors provide parameter information such as traffic densities and traffic flow by counting the number of cars that arrive at the intersection. Information on various traffic patterns is gathered using these factors.

The fuzzy logic traffic signal controller modifies the duration of the signal light.

The road is equipped with two sensors. The first sensor, which counts the number of cars passing the intersection, is positioned behind the traffic light. The second sensor, which counts the number of cars approaching the intersection, is positioned behind the first sensor. Controlling the cycle length based on traffic circumstances is the responsibility of the fuzzy logic traffic signal controller.

Methodology

To develop fuzzy logic-based Traffic Congestion Management using traffic signal control following assumptions are made

1. Traffic is arriving from the east, west, north, and south at this ch. Shivaji Maharaj Chowk, Vita four-way intersection.
2. There are two phases for traffic flow as shown in Figure 1 Traffic flows from east to west and west to east in phase 1. Traffic travels from north to south and south to north during phase 2.
3. No left and right turns are considered.
4. Pedestrian crossing is not considered.
5. The sensors are placed on a distance of 200 meters.
6. Maximum number of vehicles detected queuing is 20.

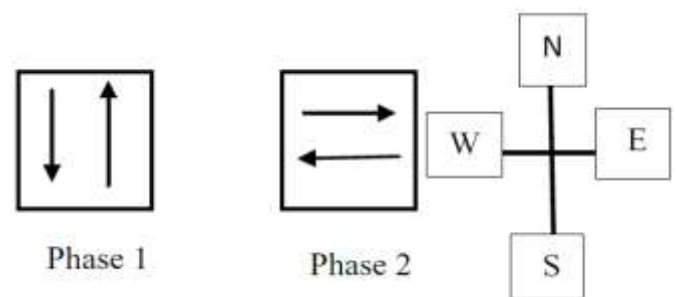


Figure 1. Location of sensors and Phase considered

fuzzy logic-based Traffic Congestion Management using traffic signal control is intended for a single, four-lane intersection (east, west, north, and south). there are two input parameters: Traffic density and traffic flow rate. The output parameter is cycle length. Hence based on the current traffic condition fuzzy rules for rule base are formulated according to which the fuzzy controller will give the cycle length.

Traffic Density: Traffic density is the number vehicles over a stretch of road. Traffic density is measured in vehicles per kilometre.

$$\text{Traffic density} = \text{No. of vehicles} / \text{Length of road.}$$

Traffic flow: Traffic flow is the rate of vehicles that pass a given cross section of a road per unit time. Traffic flow is measured in vehicles per hour.

$$\text{Traffic flow} = n(x)/t.$$

$n(x)$ = number of vehicles that pass a given road section x , t = time interval considered.

$$\text{Traffic flow} = \text{Traffic Density} * \text{Traffic Speed.}$$

Cycle length: It is the time interval in seconds a signal takes to complete one full cycle of indication.

Each of the input and output parameters for traffic signal control has five membership functions. Very small is represented by VS, small by S, medium by M, large by L, and very large by VL. The diagram for Mamdani fuzzy traffic signal control system is shown in the Figure 2. The membership functions for input parameters density and flow rate are shown in Figure 3 and Figure 4 respectively. The membership function for output parameter cycle length is shown in Figure 5.

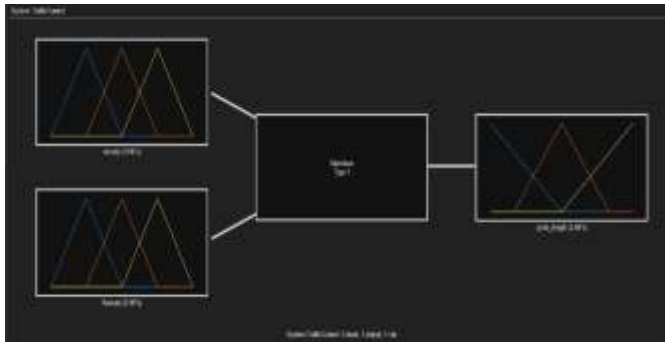


Figure 2. Mamdani fuzzy traffic signal control system

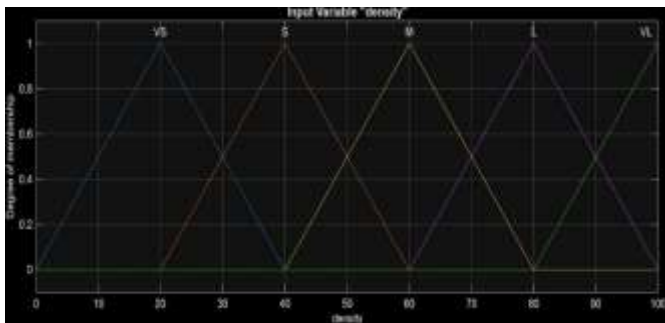


Figure 3. Membership functions for traffic density.

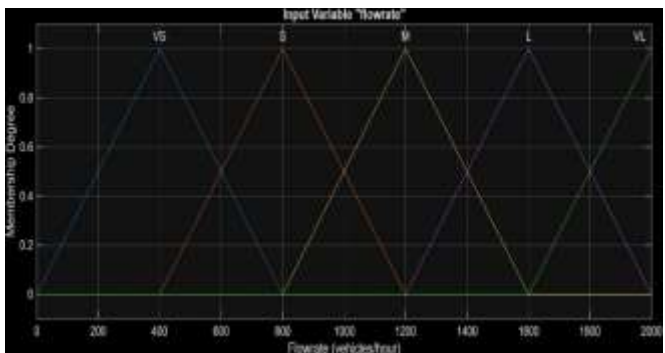


Figure 4. Membership functions for traffic flow.

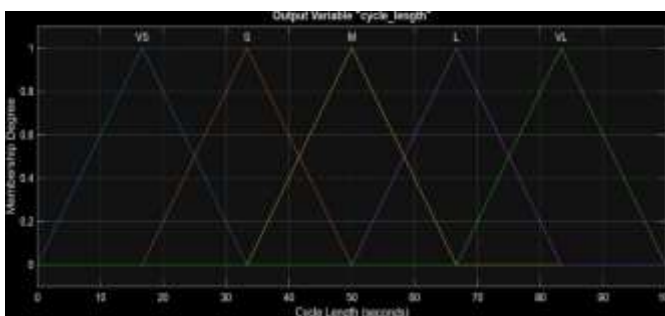


Figure 5. Membership function for cycle length.

Fuzzy Rule Set

Human reasoning is the basis for the fuzzy logic controller's inference process. Human expert knowledge serves as the foundation for the regulations. For example: If the traffic density is Large and traffic flow is Large then cycle length is Large.

There are twenty-five fuzzy rules stored in rule base. These rules show all possible combination of input parameter and tuned in such a way that best possible results are shown by repeatedly doing experiments. The fuzzy rules for fuzzy logic-based traffic signal controller system are shown below in Table 1.

RULE BASE FOR FUZZY LOGIC-BASED TRAFFIC CONGESTION MANAGEMENT USING TRAFFIC SIGNAL CONTROL.

Rule No.	Input Parameters		Output Parameter
	Traffic Density	Traffic flow	Cycle length
1	VS	VS	VS
2	VS	S	S
3	VS	M	S
4	VS	L	M
5	VS	VL	L
6	S	VS	VS
7	S	S	S
8	S	M	S
9	S	L	M
10	S	VL	L
11	M	VS	S
12	M	S	S
13	M	M	M
14	M	L	M
15	M	VL	L
16	L	VS	S
17	L	S	M
18	L	M	M
19	L	L	L

20	L	VL	L
21	VL	VS	VS
22	VL	S	S
23	VL	M	M
24	VL	L	L
25	VL	VL	VL

20	400	16.7	25.16
25	500	21.5	26.89
30	600	25	28.88
35	700	28.5	31.19
40	800	33.3	33.90
45	900	38.2	37.14
50	1000	41.7	41.05
55	1100	45.2	45.8
60	1200	50	51.9
65	1300	54.8	59.98
70	1400	58.3	70.8
75	1500	61.8	86.6
80	1600	66.7	111.4

Inference Engine and De-fuzzification

The evaluation of control rules kept in the fuzzy rule base is the task of the fuzzy inference system. Because of its computational efficiency and simplicity, the Mamdani inference system is employed in this fuzzy logic-based Traffic Congestion Management using traffic signal control.

The conversion of fuzzy output values of a fuzzy inference to crisp output values is called de-fuzzification. In this Study the min-max de-fuzzification method is used.

Results

The findings are displayed in tabular form. First, the Webster cycle length formula is used to determine the cycle length. It is then compared to the cycle length determined by the traffic signal controller based on fuzzy logic. Table 2 displays the cycle length determined by the Webster approach and fuzzy logic-based traffic signal control. Whereas the fuzzy traffic signal controller uses both density and flow rate as input parameters, the Webster formula uses only flow rate. The findings demonstrate that fuzzy logic-based Traffic Congestion Management using traffic signal control outperforms pre-timed traffic signal management based on the Webster technique. Fuzzy-based traffic signal controllers often reduce cycle length by 17.6% compared to Webster-method-based traffic signals. The results show the less cycle length timing calculated by fuzzy logic-based traffic signal control then the cycle length timing calculated by Webster Method. Due to the less cycle length timing the waiting time of the vehicles at the intersection will also be less.

TABLE I. COMPARISON OF FUZZY TRAFFIC CONTROLLER CYCLE LENGTH AND WEBSTER BASED CYCLE LENGTH.

Traffic Density	Traffic Flow	Fuzzy Traffic Controller based Cycle Length	Webster based Cycle Length
5	100	16.7	21.7
10	200	16.7	22.28
15	300	16.7	23.63

Conclusion

This paper proposes fuzzy logic-based Traffic Congestion Management using traffic signal control. The results show that the fuzzy controller is more efficient than the fixed time traffic signal by webster method. The cycle time calculated through the fuzzy controller is more efficient than the fixed time traffic signal by webster method. The performance of fuzzy controller highly depends on the fuzzy rule base so it is important to tune the fuzzy rules correctly. After performing the experiments on different input data set, we get the better performance of fuzzy logic-based Traffic Congestion Management using traffic signal control than the fixed time traffic signal control by webster method. In the proposed work an ch. Shivaji Maharaj Chowk, Vita intersection is considered.

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