Intelligent Traffic Light Control System for Isolated Intersection Using Fuzzy Logic

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Abstract

Traffic is the major problem which every country faces because of the increase in number of vehicles throughout the world, particularly in large urban areas. Therefore the need arises for simulating and optimizing traffic control algorithms to better accommodate this increasing demand. Fuzzy optimization deals with finding the values of input parameters of a complex simulated system which result in desired output. Traditional techniques may require an enormous amount of simulation runs to evaluate the system. Describes, design and implementation of an intelligent traffic lights control system based on fuzzy logic technology. Software has been developed in MATLAB to simulate the situation of an isolated traffic junction based on fuzzy logic. Simulation results show that the fuzzy logic controller has better performance and is more cost effective than fixed time controller. Moreover, Fuzzy optimization is more flexible than Traditional techniques.

Keyword: Simulation, Fuzzy logic, Intelligent Traffic lights control System, Arrival, Queue and Extension time.

1. Introduction

The monitoring and control of Road traffic is becoming a major problem in many countries. The increasing number of vehicles and the lower phase of highways developments have led to traffic congestion problem. There are many factors that lead to traffic congestion such as the density of vehicles on the roads, human habits, social behavior, and traffic light system. One major factor is due to the traffic lights system that controls the traffic at junction. Traffic policeman are deployed at traffic intersection everyday in order to overcome these congestion during peak hour, thus one of the roots of the problem is due to ineffective traffic lights controllers. With effective control the intersection, it is believed that the overall capacity and performance of urban traffic network could be resolve. With the ever increasing number of vehicles on the road, the Monitoring authorities have to find new ways or measures of overcoming such a problem. Many solutions were proposed to solve the traffic jam. Most conventional traffic surveillance systems use intrusive sensors, including inductive loop detectors, micro-loop probes, and pneumatic road tubes. However, these sensors disrupt traffic during installation and repair, which leads to a high cost installation and maintenance. In addition, over the ground sensors like videos, radars, and ultrasonic were used. These systems are also high cost and their accuracy depends on environment condition [1].

Conventional methods for traffic signal control based precise models fail to deal efficiently with the complex and varying traffic situations. They are modeled 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. Such situations can be seen in various areas of Dehradun like Darshanlal-chowk where traffic flow varies in different hours and heavy traffic flows in morning and evening timings because of large number of offices on that route. Also, in different intersections, traffic flow abruptly changes in schools timings then other daily hours. Preset Cycle Time Controllers fail in such scenarios because they could not get complete information of vehicles earlier. Also, sometimes situation arises, when some VIP movement is there, the traffic flow has to divert and control different intersections. In such situations, efficiency of human decision-making is unprecedented efficiency of human because decision-making objectives are unclear [1].

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 [2, 3,4,5,6 and 7]. These algorithms are continually improving the safety and efficiency by reducing the waiting delay of vehicles on signals. 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 [7].

Lin Zhang and Honglong Li developed Fuzzy Traffic Controller for Oversaturated Intersections [7]. They designed an algorithm to control over-saturated intersections of two-way streets with left turning movements. Jee-Hyong Lee and Hyung Lee-Kwang also designed a Fuzzy Control Model. The goal of controller is to decrease the average time delay in the whole traffic network. They assumed that special establishments named right-turning lane in the intersection allow right-turning traffic flow to pass the intersection without disturbing the other traffic flows at the same intersection. Under this assumption, right-turning traffic flow is out of the consideration of fuzzy control [8].

In this paper we discuss the implementation of an intelligent traffic lights control system for isolated intersection using fuzzy logic technology which has the capability of mimicking human intelligence for controlling traffic lights. Software based on MATLAB has been developed to simulate an isolated traffic junction. The control of the traffic lights using both conventional fixed-time and fuzzy logic controllers can be simulated in the software. Analysis on the traffic lights simulation such as waiting time, density, cost, etc. can also be made using the software. The software can also be used as an exercise for undergraduate and graduate students to understand the concept of fuzzy logic and its application to a real environment. The rules and membership functions of the fuzzy logic controller can be selected and changed and their outputs can be compared in terms of several different representations.

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 Pretimed Controller. The beauty of fuzzy logic is that it allows fuzzy terms and conditions such as “short”, “Medium”, and “long” to be quantized and understood by the computer [8, 11].

2. Literature review

In this section, we discuss different research work in the field of traffic control system. In other words this section concentrates on the use of fuzzy logic for traffic control. The first attempt made to design Fuzzy Traffic Controller was in 70s by Pappis and Mamdani [2]. After that Niittymaki, Kikuchi, Chui and other researchers [4] developed different algorithms and logic controllers to normalize traffic flow. Kelsey and Bisset also designed a simulator for signal controlling of an isolated intersection with one lane. Same work was also done by Niittymaki and Pursula [5]. They observed that Fuzzy Controller reduces the vehicle delay when traffic volume was heavy. Niittymaki and Kikuchi developed Fuzzy based algorithm for pedestrians, crossing the road.

Nakatsuyama, Nagahashi, and Nishizuka [6] applied fuzzy logic to control two adjacent intersections on an arterial with one-way movements. Fuzzy control rules were developed to determine whether to extend or terminate the green signal for the downstream intersection based on the upstream traffic. Chui was the first who uses Fuzzy Logic to control traffic in multiple intersections [4]. In this attempt, only two way streets are evaluated without considering any turnings.

In recent years, Lin Zhang and Honglong Li [7] also worked on designing Fuzzy Traffic Controller for Oversaturated intersections. Jee-Hyong Lee and Hyung Lee-Kwang [8] presented direction-varying traffic signal control but assume that right turn traffic flow do not disturb any other traffic flows in an intersection.

I.N.Askerzade (Askerbeyli), Mustafa Mahmood [3] discuss a paper entitled "Control the Extension Time of Traffic Light in Single Junction by Using Fuzzy Logic" In this paper discuss the implementation of an intelligent traffic lights control system using fuzzy logic technology which has the capability of mimicking human intelligence for controlling traffic lights. Software based on MATLAB has been developed to simulate an isolated traffic junction. Fuzzy logic technology allows the implementation of real-life rules similar to the way humans would think. For example, 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.

3. Fuzzy logic

The Fuzzy Logic tool was introduced in 1965, also by Lotfi Zadeh, and is a mathematical tool for dealing with uncertainty. It offers to a soft computing partnership the important concept of computing with words. It provides a technique to deal with imprecision and information granularity. The fuzzy theory provides a mechanism for representing linguistic constructs such as "many," "low," "medium," "often," "few." In general, the fuzzy logic provides an inference structure that enables appropriate human reasoning capabilities. On the contrary, the traditional binary set theory describes crisp events, events that either do or do not occur. It uses probability theory to explain if an event will occur, measuring the chance with which a given event is expected to occur. The theory of fuzzy logic is based upon the notion of relative graded membership and so are the functions of mentation and cognitive processes. The utility of fuzzy sets lies in their ability to model uncertain or ambiguous data. Applications of fuzzy logic occur in three primary categories: consumer products, industrial/commercial systems and decision support systems [1].

4. Description of the proposed fuzzy traffic light control system

The first traffic management systems used in Germany was implemented on roads with frequent accidents caused by fog or icy road conditions. Later, these systems were extended to detect and control traffic to increase the traffic capacity. These traffic control systems use several detection stations along the road. These stations employ magnetic sensors for traffic detection, as well as weather stations transmitting environmental data from road surface and the air layer near the ground. A central traffic control computer collects the data transmitted from the section stations. A control strategy derives an adequate speed limit for every section. The control objectives are:

- Keep traffic flowing in case of peak traffic
- Slow down traffic at the inflow to congestion
- Warn for bad weather conditions such as fog or ice

Along the road of such an "intelligent" highway, alterable road signs posted on traffic sign gantries display speed limits for each lane and display non regular events such as road work, warnings for traffic back-ups, breakdowns, an accident, or dangerous weather conditions [1]. 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 the controller with traffic densities in the lanes and allows a better assessment of changing traffic patterns. As the traffic distributions fluctuate, the fuzzy controller can change the signal light accordingly.

The general structure of a fuzzy intelligent traffic lights control system is illustrated as in Figure-1. There are two electromagnetic sensors placed on the road for each lane. The first sensor behind each traffic light 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 S from the lights. The number 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 light and can only sense the presence of a car waiting at the junction, not the number of cars waiting at the traffic. The distance between the two sensors S, is determined accordingly following the traffic flow pattern at that particular intersection. The fuzzy logic controller is responsible for controlling the length of the green time according to the traffic conditions. The state machine controls the sequence of states that the fuzzy traffic controller should cycle through. There is one state for each phase of the traffic light. There is one default state which takes place when no incoming traffic is detected. This default state corresponds to the green time for a specific approach, usually to the main approach. In the sequence of states, a state can be skipped if there is no vehicle queues for the corresponding approach.

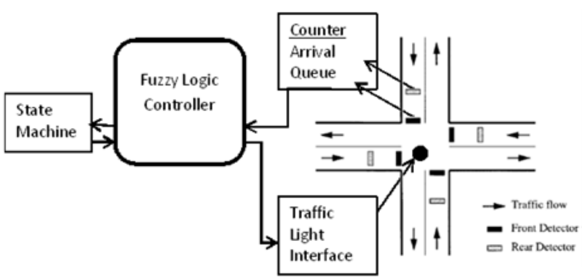

Figure 1: General Structure of fuzzy light control system

In this research, the main goals of fuzzy logic in the traffic signal control, and a matter of fact, also in traffic signal control in general, are as follows-

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

5. Methodology

In the development of the intelligent traffic lights control system the following assumptions are made:

- The junction is an isolated four-way junction with traffic coming from the north, west, south and east directions;

- when traffic from the east and west moves, traffic from the north and south stops, and vice-versa;

- no right and left turns are considered in this system;

- the fuzzy logic controller will observe the density of the north and south traffic as one side and the west and east traffic as another side;
- the East-West lane is assumed as the main approach;

The flow diagram of a fuzzy logic controller is shown in figure 3.

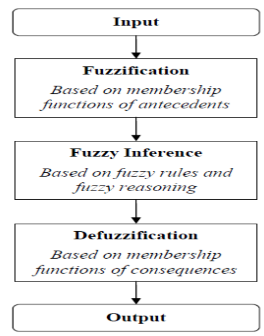

Figure 2: Structure of Fuzzy logic Controller

A fuzzy logic controller was designed for an isolated 4-lane traffic intersection: east, west, north and south as shown in Figure 1. In the traffic lights controller two fuzzy input variables are chosen: the quantity of the traffic on the arrival side (Arrival) and the quantity of traffic on the queuing side (Queue).

If the north and south side is green then this would be the arrival side while the west and east side would be considered as the queuing side, and vice-versa. The output fuzzy variable would be the extension time needed for the green light on the arrival side (Extension). Thus based on the current traffic conditions the fuzzy rules can be formulated so that the output of the fuzzy controller will extend or not the current green light time. If there is no extension of the current green time, the state of the traffic lights will immediately change to another state, allowing the traffic from the alternate phase to flow.

6. Fuzzy parameters and their membership functions design

For the traffic lights control, there are five membership functions for each of the input and there are four output fuzzy variable of the system. Table 1 shows the fuzzy input variables of Arrival, Queue and output variable

Extension of the system.

Input Variables		Output Variable	
Queue	**Arrival**	**Extension Time**	
Very-Short	Very-Short	Z	Zero
Short	Short	S	Short
Medium	Medium	M	Medium
Large	Large		
Very Large	Very Large	L	Large

Table 1: Fuzzy Variables form for Intelligent traffic light control system

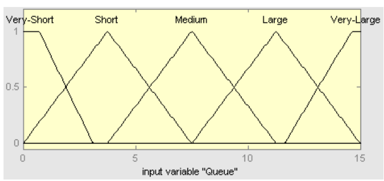

Figure 3: Queue membership

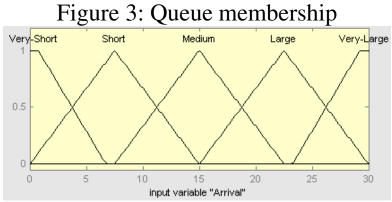

Figure 4: Arrival membership

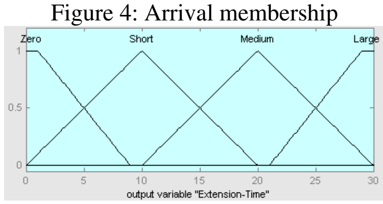

Figure 5: Extension time membership

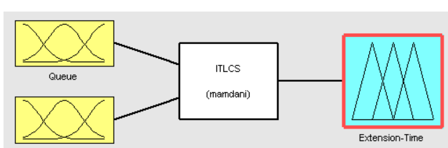

Figure 6: The whole design structure

7. Fuzzy rule set

The inference mechanism in the fuzzy logic controller resembles that of the human reasoning process. This is where fuzzy logic technology is associated with artificial intelligence. Humans unconsciously use rules in implementing their actions. For example, a traffic policeman manning a junction say, one from the north and one from the west; he would use his expert opinion in controlling the traffic more or less in the following way:

IF traffic from the north of the city is HEAVY AND traffic from the west is LESS THEN allow movement of traffic from the north LONGER

The fuzzy rule uses in intelligent traffic light control system shown in the figure 7.

1. If (Queue is Very-Short) and (Arrival is Very-Short) then (Extension-Time is Zero) (1)
2. If (Queue is Short) and (Arrival is Very-Short) then (Extension-Time is Zero) (1)
3. If (Queue is Medium) and (Arrival is Very-Short) then (Extension-Time is Zero) (1)
4. If (Queue is Large) and (Arrival is Very-Short) then (Extension-Time is Zero) (1)
5. If (Queue is Very-Large) and (Arrival is Very-Short) then (Extension-Time is Zero) (1)
6. If (Queue is Very-Short) and (Arrival is Short) then (Extension-Time is Short) (1)
7. If (Queue is Short) and (Arrival is Short) then (Extension-Time is Short) (1)
8. If (Queue is Medium) and (Arrival is Short) then (Extension-Time is Short) (1)
9. If (Queue is Large) and (Arrival is Short) then (Extension-Time is Zero) (1)
10. If (Queue is Very-Large) and (Arrival is Short) then (Extension-Time is Zero) (1)
11. If (Queue is Very-Short) and (Arrival is Medium) then (Extension-Time is Medium) (1)
12. If (Queue is Short) and (Arrival is Medium) then (Extension-Time is Medium) (1)
13. If (Queue is Medium) and (Arrival is Medium) then (Extension-Time is Medium) (1)
14. If (Queue is Large) and (Arrival is Medium) then (Extension-Time is Short) (1)
15. If (Queue is Very-Large) and (Arrival is Medium) then (Extension-Time is Short) (1)
16. If (Queue is Very-Short) and (Arrival is Large) then (Extension-Time is Large) (1)
17. If (Queue is Short) and (Arrival is Large) then (Extension-Time is Medium) (1)
18. If (Queue is Medium) and (Arrival is Large) then (Extension-Time is Medium) (1)
19. If (Queue is Large) and (Arrival is Large) then (Extension-Time is Medium) (1)
20. If (Queue is Very-Large) and (Arrival is Large) then (Extension-Time is Short) (1)
21. If (Queue is Very-Short) and (Arrival is Very-Large) then (Extension-Time is Large) (1)
22. If (Queue is Short) and (Arrival is Very-Large) then (Extension-Time is Large) (1)
23. If (Queue is Medium) and (Arrival is Very-Large) then (Extension-Time is Medium) (1)
24. If (Queue is Large) and (Arrival is Very-Large) then (Extension-Time is Medium) (1)
25. If (Queue is Very-Large) and (Arrival is Very-Large) then (Extension-Time is Short) (1)

Figure 7: Fuzzy rule decided the length of extension time

8. Inference engine and defuzzification

In the fuzzy logic controller once the appropriate rules are fired, the degree of membership of the output fuzzy variable i.e., Extension time, is determined by encoding the antecedent fuzzy subsets, in this case Arrival and Queue. In the traffic lights fuzzy control system, the max-min implication technique is used. Using this technique, the final output membership function for each rule is the fuzzy set assigned to that output by clipping the degree of truth values of the membership functions of the associated antecedents. Once the membership degree of each output fuzzy variable is determined, all of the rules that are being fired are then combined and the actual crisp output is obtained through defuzzification. There are several of defuzzification methods; here we use the center of gravity defuzzification technique.

Arrival → Queue↓	Very-Short	Short	Medium	Large	Very-Large
Very-Short	Z	S	M	L	L
Short	Z	S	M	M	L
Medium	Z	S	M	M	M
Large	Z	Z	S	M	M
Very Large	Z	Z	S	S	S

Table 2: Fuzzy rules matrix form for the intelligent traffic lights control System

9. Simulation result

After the intelligent traffic light control system was carefully designed, we test the system and discuss the impact of the input variables on the output variable. The simulation we show the effect of the two inputs to resulted extension time.. This system shows the slow growing in the time that will added to the cycle which make the traffic situation more stable. The simulation implemented in three stages. In each stage we test one of the inputs with other input and discuss their effect on the output extension.

No. of Vehicle at Queue side (Max R.=15)	No. of Vehicle at Arrival side (Max R.=30)	Extension time (Centroid method) (Max R.=30)
2	2	7.73
3	3	8.07
6	6	9.89
9	9	11.8
12	12	9.19
15	15	10
3	6	9.9
3	9	12.4
3	12	15.8
3	18	20
3	20	20
3	25	20.5
3	30	26.9
6	3	8.15
9	3	8.15
12	3	3.33
15	3	3.33

Table 3: Extension time at different values of input variables arrival and queue side

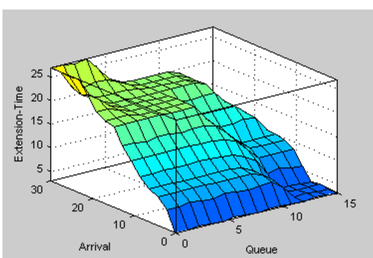

Figure 8: Input variables Arrival, Queue Vs output variable Extension- time

As shown in figure 8 as well as in Table 3 with the different inputs, the extension time (z-axis) is small when the density of arrival (y-axis) is small and the density of the queue side (x-axis) is also small. Unlike the other method, here the external time grows slowly its being large only when the arrival side density is very short to large values and the queue side density is very shot value. In other words, the external time grows slowly its being large only when the arrival side density increases and the queue side density is constant. On the other hand if arrival side density being constant and the queue side density increases then extension time goes to medium to short. This is an important difference between other methods.

10. Conclusion

The fuzzy logic traffic lights controller performed better than the fixed time controller or even vehicle actuated controllers due to its flexibility. The flexibility involves the number of vehicles sensed at the incoming junction and the extension of the green time. In the fixed time controller, being an open loop system the green time is not extended whatever the density of car at the junction. In addition to the fuzzy variables as mentioned, the fuzzy controller also has an advantage of performing according to linguistics rules in the manner of how a human would use. In this paper a basic intelligent traffic light control system for isolated intersections using fuzzy logic was developed.

In the intelligent traffic light control system, the extension time is not a fixed value. They are all fuzzy variables such as zero, short, medium and large. The numbers of cars sensed at the input of the fuzzy controller are also converted into fuzzy values, such as very short, short, medium, large and very large. In addition to the fuzzy variables as mentioned, the fuzzy controller also has an advantage of performing according to linguistic rules in the manner of how a human would use. The reasoning method in the fuzzy controller is also similar to that of the policeman handling the traffic flow at a typical junction.

It can be observed from the results that the intelligent traffic light control system provides better performance in terms of total waiting time as well as total moving time. Less waiting time will not only reduce the fuel consumption but also reduce air and noise pollution. It also shows that it can reduce the traffic congestion and avoids the time being wasted by a green light on an empty road.

11. References

[1] Javed Alam and Dr. M.K. Pandey "Development of Traffic Light Control System for Emergency Vehicle Using Fuzzy Logic" International Conference on Artificial Intelligence and Soft Computing, IIT- BHU Varanasi, India 7-9 December-2012.

[2] Pappis, C. P., and E. H. Mamdani. "A Fuzzy Logic Controller for a Traffic Junction". IEEE Transactions on Systems, Man, and Cybernetics, Vol. SMC-7, No. 10, October 1977, pp. 707-717.

[3] I.N.Askerzade (Askerbeyli), Mustafa Mahmood "Control the Extension Time of Traffic Light in Single Junction by Using Fuzzy Logic" International Journal of Electrical & Computer Sciences IJECS-IJENS Vol:10 No:02 in 2010.

[4] Chiu, S. "Adaptive Traffic Signal Control Using Fuzzy Logic". Proceedings of the IEEE Intelligent Vehicles

Symposium, 1992, pp. 98-107.

[5] Niittymaki, J., and M. Pursula. “Signal Control Using Fuzzy Logic. Fuzzy Sets and Systems”, Vol. 116, 2000, pp. 11-22.

[6] Nakatsuyama, M., H. Nagahashi, and N. Nishizuka. “Fuzzy Logic Phase Controller for Traffic Junctions in the One-Way Arterial Road”. Proceedings of the IFAC Ninth Triennial World Congress, 1984, pp. 2865-2870.

[7] Li, H., P. D. Prevedouros, and L. Zhang. “Signal Control for Oversaturated Intersections Using Fuzzy Logic” Submitted for consideration for presentation at the 2005 Annual Meeting of the TRB and publication in the Transportation Research Record.

[8] Hong Wei, Wang Yong, Mu Xuanqin and Wu Yan. “A cooperative fuzzy control method for traffic Lights”. 2001 IEEE Intelligent Transportation Systems Conference Proceedings - Oakland (CA), USA - August 25-29, 2001.

[9] Yi Hu, CQU, Peter Thomas, Member, IEEE, and Russel J. Stonier, Member, IEEE. “Traffic Signal Control using Fuzzy Logic and Evolutionary Algorithms”. 2007 – IEEE.

[10] J Niittymaki, R Nevala, E Turunen. “Fuzzy Traffic Signal Control and a New Inference Method! Maximal Fuzzy Similarity - Fuzzy Sets and Systems”, 2003 - iasi.rm.cnr.it

[11] Marco Wiering, Jelle van Veenen, Jilles Vreeken, Arne Koopman. “Intelligent Traffic Light Control”. Institute of information and computing sciences, Utrecht university technical report UU-CS-2004-029.