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Introduction of Traffic Light Controller with Fuzzy Control System

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Abstract
Vehicular travel is increasing throughout the world, particularly in large urban areas. With the increasing use of automobiles in cities traffic congestion occurred. So there is requirement for optimizing traffic control methods to better accommodate this increasing demand. So as the transportation system will continue to grow, intelligent traffic controls have to be employed to face road traffic congestion problems. Fuzzy controllers have been widely used in many consumer products and industrial applications with success over the past two decades. For traffic control, however, fuzzy controllers have not been widely applied. This paper proposes a fuzzy traffic lights controller to be used at a complex traffic junction.The real time parameters such as traffic density and queue length are obtained by using image processing techniques. So the on and off timings for the green, red and orange lights are adjusted as per the actual road conditions. Fuzzy logic has been widely used to develop a traffic signal controller because it allows qualitative modeling of complex systems. This paper describes a fuzzy logic signal controller for a four–way intersection suitable for mixed traffic, including a high proportion of motorcycles. This paper discusses the traffic control strategy, which dictates the design criteria for the fuzzy logic controller. The components of fuzzy logic controller-the fuzzifier, the fuzzy rule base formulated by human experts, the fuzzy inference engine and the defuzzifier.

Keywords
Traffic Control, Fuzzy Logic, membership function, Intelligent Transportation Systems (ITS), Defuzzification

I. Introduction

Traffic congestion is a severe problem in many modern cities around the world. Traffic congestion has been causing many critical problems and challenges in the major and most populated cities. To travel to different places within the city is becoming more difficult for the travelers in traffic. Due to these congestion problems, people lose time, miss opportunities, and get frustrated. Traffic congestion directly impacts the companies. Due to traffic congestions there is a loss in productivity from workers opportunities are lost, delivery gets delayed, and thereby the costs goes on increasing. To solve these congestion problems, we have to build new facilities and infrastructure. The only disadvantage of making new roads on facilities is that it makes the surroundings more congested. So for that reason we need to change the system rather than making new infrastructure twice. The Main goals of this paper are improving safety, minimizing travel time and increasing the capacity of Infrastructures. Such improvements are beneficial to health, economy and the environment. Delay reduction at city intersections and travel time savings are major goal of Intelligent Transportation Systems (ITS) Traffic load is highly dependent on parameters such as time, day, season, weather and unpredictable situations such as accidents, special events or constructional activities. If these parameters are not taken into account, the traffic control system will create delays. A traffic control system that sozlves these problems by continuously sensing and adjusting the timing of traffic lights according to the actual traffic load is called an Intelligent Traffic control System (ITS) [3,12]. ITS moves a broad range of applications from basic traffic signal control system to advanced systems that provide operational benefits to the transportation system: reduce congestion, reduce operational costs, provide alternate routes to travelers, enhances productivity and increase the capacity of infrastructure [2]. Under these circumstances, the traffic control on urban expressways is generally dependent upon the operators' judgment, For example, fully experienced operators are always working to optimize the traffic conditions, at the console desk in the traffic control center. The problems in the case of human traffic control are as follow:

- Only skilled operators can make suitable judgments and decision, because the situation is very complicated and many factors should be considered at control;
- The work load of skilled operators is very high, because they always make decisions according to traffic condition at very short time intervals;
- It is very difficult to improve the process of traffic control, because the actual process of the operators' judgment is not described clearly.

To solve these problems, it becomes necessary to formulate the operators' judgment and to develop an automatic decision-making system in place of operators. If the system is establish, a more effective traffic control process can be constructed and the actual situation of traffic control is investigated. Secondly, the decision process of the operator is described by the method of fuzzy logic control that is useful to express human fuzziness.

II. The Present Day Technique

Today we live in the world of automation. Microcontrollers control most things around us. The control of traffic lights is well known area where this type of control system is incorporated, which controls the four sets of traffic lights at the traffic crossing. . But, the control is not flexible, based on the condition of traffic at the crossing. Rather, the on and off time periods are fixed for the red, green and orange lights. These timing durations are varied as per the day, the day of the week etc. But there are no real time adjustments of the on/off times as per the traffic conditions on the crossing. This is ordered to work such that the traffic in only those directions , which do not cross each others, is allowed to move at any given time while in all the other directions, the traffic is forbidden to move. For example in INDIA (left hand drive system) the traffic may be allowed to move both from north to south and from south to north, while the east to west direction, the east to north direction, the west to east direction, the west to south direction and the south to east direction are blocked at that time as shown in Fig. 1 [9]

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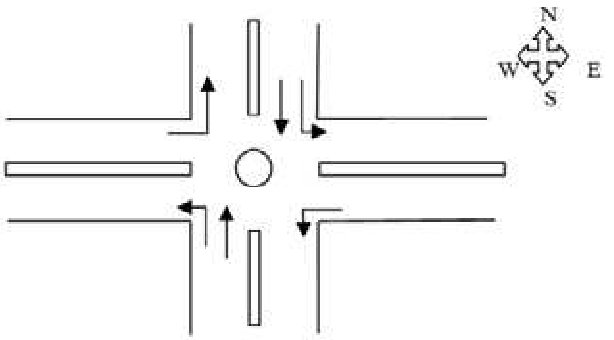

Fig. 1: Present day technique for control or traffic light (Left hand side traffic)

So the traffic lights which exist in the junction work according to an algorithm which does not take into account the number of vehicles which arrive at the crossroad. Inefficient configuration of traffic lights based in a fixed cycle protocol can lead to unnecessarily long waiting times for vehicles and even to traffic congestion. Simplifying, in this case, this paper presents a possible solution using the fuzzy logic. It is an approach that allows the implementation of real-life rules by using computer algorithm.

III. The Proposed Technique

Traffic signal control is one measure that is commonly used at road intersections to minimize vehicular travel times and delays [5]. Traffic signal control at road intersections allows vehicle movements to be controlled by allocating time intervals, during which separate traffic demands for each approach of the intersection can make use of the available road space. Traffic signal control in most signalized intersections is done with fixed time signal control. Under fixed time control, all signal timing parameters are pre-computed and kept constant. These parameters are calculated based on historical traffic data. This method usually shows good results in normal traffic conditions, but sometimes they fail to cope with complex, time varying traffic conditions. Vehicle actuated (VA) control presents an improvement over fixed time control [6]. The VA control principle aims to adjust the length of green time in response to the real traffic flow variations. VA control requires vehicle detectors to provide accurate information of traffic in real-time. This method has limited ability to respond to real-time traffic demand, where its performance generally deteriorates with heavy traffic conditions. To overcome such problems adaptive traffic signal controllers are designed to address those deficiencies. Fuzzy logic has been used widely to develop an adaptive traffic signal controller, because it allows qualitative modeling of complex systems, where it is not easy to solve using mathematical models and is good for systems that have inherent uncertainties. Many researchers have proposed the traffic signal control systems using fuzzy logic. They proposed a FLSC for an isolated intersection of four-way east-west/north-south without turning movement. This gives generally a better performance of the FLSC when compared to fixed time and actuated controllers. However, all existing research has developed FLSC based on non-mixed traffic conditions (developed countries), [11] where they considered the passenger car only and neglect motorcycles in their traffic. It is quite different to that in mixed traffic conditions (developing countries), where the traffic streams are heterogeneous, consisting of different types of vehicle with wide variation in their static, dynamic and operating characteristics, and with a particularly high proportion of motorcycles. Due to lack of lane discipline, queues at intersections are built up based on the optimum road space utilization which means vehicles can occupy any position across the road based on the available space. It is obvious that traffic behavior in mixed traffic conditions is different to that in non-mixed traffic conditions. Therefore, the main objective of this research is to design an adaptive fuzzy logic signal controller for an isolated four-way intersection with reference to mixed traffic (including high proportion of motorcycles) [14]. Simulations are used to examine and analyze the effectiveness of the proposed FLSC. Then, the performance of the proposed controller is contrasted with an optimized fixed time controller.

IV. Degisn Creteria And Constraints

In the development of the fuzzy traffic light 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 north and south moves, traffic from the west and east stops, and vice versa;
- No right and left turns are considered;
- 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.

V. Design For Fuzzy Logic Traffic Light Controller

A fuzzy logic controller is designed for an isolated 4-Lane traffic intersection: North, South, East and West [4,5]. In this method we consider two fuzzy input variables and one output fuzzy variable. These input variables are:

- Quantity of the traffic on the arrival side (Arrival);
- Quantity of traffic on the queuing side (Queue).

If the north and the 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.

On the other side the output variable would be the extension time needed for the green light on the arrival side. So based on the current traffic conditions the fuzzy rules can be formulated so that the output of the fuzzy controller will approaches to increase or not increases the current green light time. During these methods some points to be remember, which are:

- The four traffic lights work in four sequences, every light having a variable sequence from 10 to 130 seconds depending on the congestion (the number of vehicles from the queue bur also the number of one's which arrive every minute);
- All the four traffic lights will be controlled by this same mechanism;

If there is no extension of the current green light time, the state of the traffic lights will immediately change to another side which allows the traffic from the alternate traffic flow. In Fuzzy controller structure input 1 (I/P 1) is the arrival of the vehicles and input 2 (I/P 2) is the queuing of vehicles are two parameters which are used to set the extension time for green light are fuzzified and then these parameters are given to fuzzy inference system which actually sets the time but fuzzy in nature which are actually different parameters (decrease, constant, increase) so to convert these performance parameters in crisp we use defuzzification method as shown in Fig. 2 which gives the actual time for what time the green light is ON or OFF [7] [8].

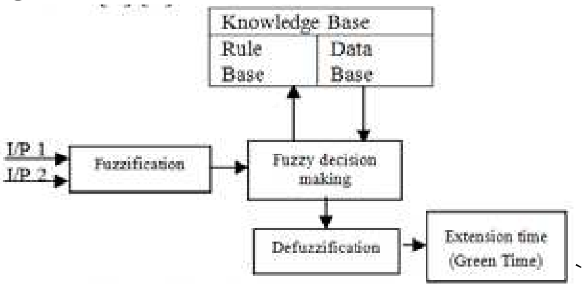

Fig. 2: Fuzzy controller structure

When the transportation needs is large, the signal cycle should be increased. The upper bound should not be more than 130 seconds generally, because the driver on the opposite direction may not tolerate that the signal cycle is more than 130 second India. So minimum and maximum signal cycle is set for each phase. When transportation needs is small, the minimum signal cycle is run. On the other side when the transportation needs is large, the maximum signal cycle is the present cycle and traffic congestion is avoided [1].

VI. Membership Functions

The types of membership function used in this paper are triangular and trapezoidal due to the computational efficiency. Membership function of each input and output fuzzy variable of FLSC is as follows:

- Membership function for the number of vehicles on the queuing side;
- Membership function for the number of vehicles which arrive at the crossroad;

The quantity of the traffic on the arrival and queuing side have {very small, small, medium, large, very large} and extension time has {decrease, constant, increase} linguistic variables [3].

A possible membership function for number of vehicles which are standing or queuing in the line at the traffic lights is represented as shown in Fig. 3.

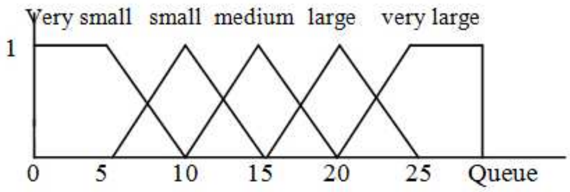

Fig. 3: The membership function for the number of vehicles which are standing in queue at the traffic

The membership functions for the number of vehicles which are standing in queue at the traffic. A possible membership function for number of vehicles which arrive at the crossroad is represented as shown in Fig. 4.

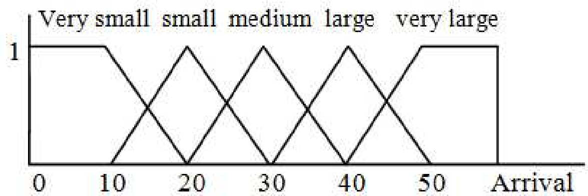

Fig. 4: The membership function for the number of vehicles which arrived at the crossroad

The membership functions for the number of vehicles which are arrive at the crossroad. A possible membership function for the allocated time for the extension time for the green light is below allocated to the Green light in Fig. 5.

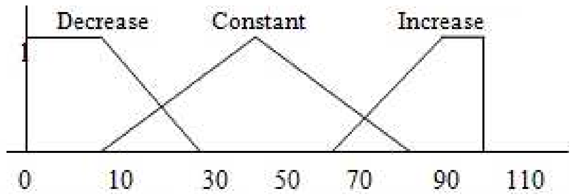

Fig. 5: The membership function for allocated time for the extention time or green light.

VII. Fuzzy Rule Base And Establishment

The basic function of the fuzzy rule base is to represent the expert knowledge in a form of IF-THEN rule structure combined with AND/OR operators. For e.g. IF traffic from the north of the city is more AND traffic from the west is less THEN allow movement of traffic from the north side [5,13].

The fuzzy rule base is set of fuzzy rules. It maps the combination of fuzzy inputs (arrival, queuing linguistic variables) to the corresponding fuzzy output. In this paper we consider A stands for arrival, Q stands for queuing and T stands for time required for green light. They are divided into different fuzzy subsets,

A= {VS, S, M, L, VL}
Q= {VS, S, M, L, VL}
T= {D, C, I}

Where VS is Very Small, S is Small, M is Medium, L is Large, VL is Very Large, D is Decrease, C is Constant, I is Increase. There are normally many rules for each decision. There are lot of rules for each decision. Some of the fuzzy rules defined presented below:

- If the number of vehicles waiting in line or queuing (Q) is medium and the number of vehicles which arrive or arrival (A) is small then the allocated time for the green light (T) decreases.
- If the number of vehicles waiting in line or queuing (Q) is large and the number of vehicles which arrive or arrival (A) is small then the allocated time for the green light (T) constant.
- If the number of vehicles waiting in line or queuing (Q) is very large and the number of vehicles which arrive or arrival (A) is medium then the allocated time for the green light (T) increases.
- If the number of vehicles waiting in line or queuing (Q) is very small and the number of vehicles which arrive or arrival (A) is medium then the allocated time for the green light (T) decreases.

From Table 6 we can easily understand the different fuzzy rules with different parameters i.e arrival and queuing.

Table 1: Fuzzy control rules

Queue Arrival	VS	S	M	L	VL
VS	D	D	D	D	C
S	D	D	D	C	C
M	D	D	C	C	I
L	D	C	C	I	I
VL	C	C	I	I	I

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VIII. Inferrence Engine and Defuzzification

Membership functions are used to retranslate the fuzzy output into a crisp value. This method is known as Defuzzification [4]. The fuzzy inference evaluates the control rules stored in the fuzzy rule base. Defuzzification is a process to convert the fuzzy output values of a fuzzy inference to real crisp values. Fist a typical value is computed for each term in the linguistic variable and finally a best compromise is determined by balancing out the results using different methods like center of sum, center of area, center of area mean of maximum etc. But for this application we use Center of Sum to process defuzzification of the output variable extension time. This method is mostly used because this method has better performance in terms of continuity, computer complexity and counting.

IX. Conclusion and Future Works

The system proposed here is very flexible. The feedback of the queue length and traffic densities can be taken from images taken from cameras. Because of the flexibility of the fuzzy logic in dealing with uncertainty, it can be used advantageously for traffic light controlling systems. The proposed FLSC and fixed time controller produces little difference in results in terms of constant traffic flow while in the case of time varying traffics, the proposed FLSC is superior to the fixed time controller [2] [8] [11]. This controller gives a suitable green time to improve the traffic capacity effectively and reduced the intersection delay, which can insure vehicles don't allow waiting too long on the road. While in the case of fixed time controller when green time is finished, this will give the green time to the next phase even if the current vehicle flow is large. So arriving vehicles must wait for the next cycle to leave. The performance of the FLSC is affected by the configuration of the membership functions of the input and output variables and the rule base . It can be observed that fuzzy logic control system provides better performance in terms of improving the safety and efficiency by reducing the waiting delay of vehicles on signals. Less traffic congestion and less waiting time at red traffic lights will reduce the fuel consumption, air pollution, sound pollution, and time and energy waste. Furthermore, with the comparative ease terms like weather conditions, environments aspects etc. can be added to the fuzzy system. A lot of research work has to be done to verify the expected features by simulation. The definitions of the fuzzy sets of the antecedents are also very easily changeable. This is a very promising application of fuzzy logic in practical areas, and will be highly useful in traffic control in the today congestion traffic.

References

[1] Akçelik, R., Besley, M., Roper, R., "Fundamental Relationships for Traffic Flows at Signalized Intersections, ARRB Transport Research Ltd.," Research Report No. 340,pp. 268 , ISBN 0869107968, 1999

[2] A. Hegyi, B. De Schutter, R. Babuska, S. Hoogendoorn, H. VanZuylen, H. Shuurman, "A Fuzzy Decision Support System for Traffic Control Centers[J]", Faculty of Information Technology and Systems, Aug. 2001, pp.358-363.

[3] Beauchamp-Baez,G., Rodriguez-Morales, E., Muniz Marrero, E.,L., "A Fuzzy Logic Based Phase Controller for Traffic Control", Proc. IEEE International Conference on Fuzzy Systems 1997, pp.1533-1539.

[4] Dr. Devinder Kaur, Elisa Konga, Esa Konga, "Fuzzy Traffic Light Controller, Circuits and Systems" 1994, Proceedings of the 37th Midwest Symposium pp.1507-1510 Vol.2, August,1994.

[5] Hoyer, R., Jumar, U., "Fuzzy Control of Traffic Lights", Proc. IEEE International Conference on Fuzzy Systems, 1994, pp 1526-1531.

[6] Jee-Hyong Lee, Hyung Lee Kwang, "Distributed and Cooperative Fuzzy Controllers for Traffic Intersections Group", IEEE Transactions on Systems, Man, and Cybernetics- Part C : Applications and Reviews, Vol. 29, No. 2, May, 1999

[7] Kosonen, T., "Fuzzy logic based traffic signal control". Helsinki University of Technology, Transportation Engineering. Master's thesis, 2002. pp.146

[8] Lin, Q., Kwan, B.W., Tung, L.J., "Traffic Signal Control Using Fuzzy Logic", Proc. IEEE International Conference on Fuzzy Systems 1997, pp. 1644-1649.

[9] Lisakki Kosonen , "Multi-Agent fuzzy signal control based on real-time simulation", Helsinki University of Technology, Transportation engineering, Finland. Transportation research Part C 11 (2003) pp. 389-403

[10] Niittymaki, J., "Fuzzy traffic signal control--Principles and applications". Doctoral thesis. Helsinki University of Technology, Transportation Engineering pp.103, 2002

[11] Niittymaki, J., Nevala, R., "Multi-level and multi-objective traffic signal control using fuzzy methods". Conference Proceedings of the 6th International Conference on Applications of Advanced Technologies in Transportation Engineering. Technical session 13, Real-time traffic control. Singapore, 28-30 June 2000. pp.11

[12] Pappis, C., Mamdani, E.,"A fuzzy logic controller for a traffic junction". IEEE Trans. Systems, Man Cybernetics SMC-7 (10), pp. 707-717, 1977.

[13] Qinghui Lin, B.W. Kwan, L.J. Tung, "Traffic Signal Control Using Fuzzy Logic", Systems, Man and Cybernetics, 1997. Computational Cybernetics and Simulation, 1997 IEEE International Conference pp. 1644-1649, Vol. 2. October. 1997.

[14] Xu Li-qun, Jiang Fu, "Fuzzy Reasoning Algorithm for Control of Traffic in Congestion Route[J]", Information and Control, Apr.2003, Vol.32, No.2, pp. 132-141.

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