Optimal Traffic Signal Cycle using Fuzzy Rules

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Abstract:

In order to produce an optimal traffic cycle. We must first check how many waiting cars are at the lower intersection, because waiting queue is bigger than the length of upper traffic intersection. Start up delay time and vehicle waiting time occurs. To reduce vehicle waiting time, in this paper, we present an optimal green time algorithm using fuzzy neural network. Through computer simulation has been proven to be improved average vehicle speed than fixed traffic signal light which do not consider different intersection conditions.

요약

최적 교통 주기를 산출하기 위해서는 하위교차로에 대기차량이 얼마나 있는지를 점검해야 한다. 왜냐하면 대기차량이 상위교차로의 길이보다 크면 출발 지연 시간 및 승용차 대기시간이 발생하기 때문이다. 승용차 대기시간을 단축시키기 위해서 본 논문에서는 퍼지 신경망을 이용한 최적 연동 녹색시간 알고리즘을 제안한다. 컴퓨터 모의실험을 통해서, 서로 다른 교차로 조건을 고려하지 않은 고정 교통신호등 보다 평균 주행속도가 향상 된 것을 입증하였다.

Keywords: fuzzy rules, vehicle waiting time, optimal green time,

1. Introduction

This paper proposes a optimal traffic cycle considering capacity of traffic intersection that analyzes transportation network flows in case of saturated flows where there are traffic accident area, under construction of telephone and sharp curves of road. In this paper, it proposed that we determine optimal traffic cycle using fuzzy rules. Moreover to prevent spillback and increase vehicle waiting time. it can adapt control itself when sensing upper traffic intersection and different saturation rate, road length, road slopes and road width, we can create optimal green time using fuzzy rules[1-4].

Traffic congestion occurs on all road environments in one form or another. First there is the slow crawl along busy shopping street and construction work in the road, then the long queues that form when accidents occur on the roads, and the rapid, unpredictable slowing down and speeding up of traffic on overloaded in the traffic intersection[5-6].

Congested operations characterize the entire range of operations which may be experienced when traffic demand approaches or exceeds the road and junction capacity[7-8]. The complex interactions between control strategies, congestion levels, and driver behavior have made an accurate prediction of time dependent vehicle arrival patterns. Technically, to capture the intersection traffic dynamics, based on either arriving flows or queue length, a proposed model must capable of taking into account all traffic related vehicles in the two neighboring intersections. It includes capacity of traffic intersection, length of traffic intersection, and number of lanes[9-11].

If capacity of traffic intersection is over than 100%. Even though, good car navigation system does not create which is the shortest path. In this paper, it will be able to forecast the optimal traffic information, when length of vehicle, vehicle speed and width of road. With computer simulation, we prove that the spillback phenomenon generated under highly saturated traffic condition is improved using fuzzy logic. This paper is organized as follows: Section 2 briefly explain the problem of conventional traffic light. Section 3 presents fuzzy rule base for optimal green time. Section 4 describe determination of optimal traffic cycle using fuzzy logic computer simulation. Finally, section 5 will give conclusions.

2. Capacity of traffic intersection

The three most important characteristics of traffic are flow, speed, and concentration. Before attempting to model these characteristics, it is essential to definitions are related to the methods of measurement, as well as to the methods of averaging the measurements.

Traditionally, the traffic engineer has used volume or flow as one of the primary measures of traffic condition or state. Consider the situation portrayed in

It can't be applied to data of movable vehicles. Because distance of each road is not the same, and the number of congested vehicles, the number of accumulated vehicles and the number of waiting vehicles are different in each lane.

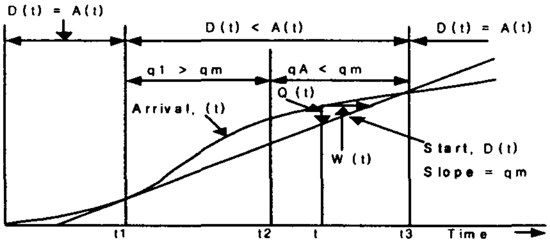


Fig. 1 Capacity of traffic intersection depending on waiting vehicle

Figure 1 explains a waiting line from t1 to t3. A moment t within t1 and t3 has a waiting line length, Q(t)=A(t)-D(t).

The perpendicular arrow Q(t) indicates the volume of vehicles accumulated after the red light turns on, and the horizontal arrow W(t) the time for which a vehicle arrives and departs. Therefore the vehicle that arrives after t second can depart after W(t). The whole waiting time is the area between the curves of arrival and departure and the length of waiting line is highest at t2 when the arrival rate is the same as qm. If one could at any instant measure the lengths of all vehicles on a given roadway and then compute the capacity of traffic intersection.

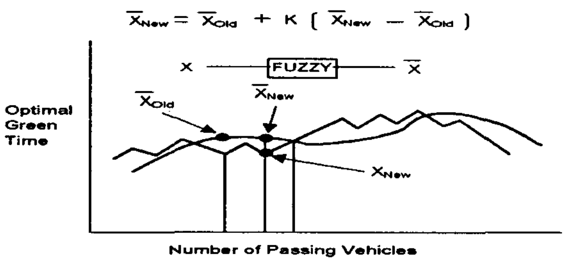


Fig.. 2 Optimal green time depending on traffic volume

The more important thing is overflows into the bottlenecks result in apparent violations of the outflow rates into bottlenecks might be smaller than the inflows. Now days, the traffic congestion has increased steadily in urban network. Moreover, if there are car accident and under construction work of telephoned, it is very difficult to calculate optimal green time. Because these roads are already to occupied with many cars and it is not easy to enter the vehicles in the road.

So, in this paper, traffic control for coordination of traffic signal considering safety or switch off the green time are proposed a avoid traffic congestion, car accident, and informing the emergency passing vehicle considering safety as shown in fig 2.

An optimum traffic cycle length formula was developed by webster for pre timed application.

This formula yields the cycle length that will produce minimum total vehicle delay.

3. Fuzzy knowledge rule base

The traffic volume balance is held at each signalized intersection of the traffic network for a certain sampling period. It can be described by the following equation.

$C_e(green) = G_{rte}(car) + G_{rti}(car) - G_{rto}(car)$

where :

$G_{rte}(car)$: Excess incoming traffic cars

$G_{rti}(car)$: Incoming traffic cars

$G_{rto}(car)$: Outgoing traffic cars

In order to determine number of vehicles for straight, it must get number of right turn and straight. Because many roads are used same line as a right turn and straight. If there are so many vehicles in the line, we can not know how many vehicle go to straight or right turn. Therefore to determine optimal green time, it must predict the number of straight turn not a turn right.

$C_e(green) = C_{xe}(in) * R_{tn}(exp\_in) + S_{tr}(exp\_in)$

$C_{rt}(green) = N_l * W_L * C_{xl}(in, out)$

where :

$C_{xe}(in)$: Excess incoming traffic cars

$R_{tn}(exp\_in)$:expected cars for right turn

$S_{tr}(exp\_in)$: expected cars for straight

The capacity at each signalized intersection is evaluated summing up each lane capacity as follows. If capacity of upper traffic intersection is bigger than capacity of lower traffic intersection, it will be alright to go vehicles for green time. But, if If upper capacity of traffic intersection is bigger than capacity of lower traffic intersection, it will be alright to go vehicles for green time. Moreover to prevent spiilbak, it must check the capacity of intersection. X_{cap}(cars, length, lanes)upper > X_{cap}(cars, length, lanes)lower.

In this paper the traffic signal control system of the traffic congestion length is to considered 1 ~ 3 coordinated intersections as follows.

for 2 lanes of the traffic intersection,

$$J_i(car) = \sum_i (S_{tr}(car) + R_{tn}(car))$$

for 4 lanes of the traffic intersection,

$$J_i(car) = \sum_i \sum_j (S_{tr}(car) + R_{tn}(car))$$

for 6 lanes of the traffic intersection,

$$J_i(car) = \sum_i \sum_j \sum_k (S_{tr}(car) + R_{tn}(car))$$

4. Design of optimal fuzzy traffic cycle

Let's think about how many cars are in the upper traffic intersection at rush hour. At this time, let's assume that high saturation degree of upper traffic intersection conditions of a, b ,c ,d are 0.6, 0.4, 0.3, 0.9. Low saturation degree of lower traffic intersection conditions are P_1, P_2, P_3.

In other words, there are so many cars in the upper traffic intersection but, there are a few cars in the lower traffic intersection.

Let's inferences the degree of saturation when estimating of passing vehicles start from upper traffic intersection and entering to the lower traffic intersection.

The numbers above in the line are lanes and length of traffic intersection. Capacity of traffic intersection is very closely related with lanes of width of traffic intersection as shown in Fig 3..

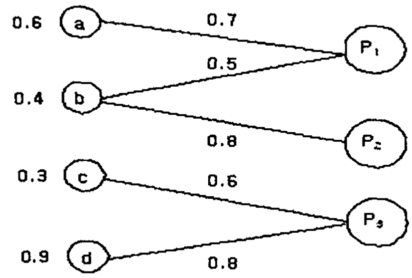


Fig. 3 Fuzzy conversion factor for length of traffic intersection

The important thing is to prevent spillback and estimate how many vehicles can enter the upper traffic intersection. If lower traffic intersections and upper traffic intersections consist of equal 4 lanes and 100 meter for length of traffic intersection. It must extend the optimal green time when there are so many vehicles in the traffic road. But, it must reduce the optimal traffic cycle when there are a few vehicles on the traffic road or capacity of passing vehicles for upper traffic intersection is smaller than capacity of lower traffic intersection. in order to prevent the spillback and optimal traffic cycle we must consider width and length of traffic intersection.

In this paper, we will introduce about fuzzy extension set of *different traffic intersection*. The following shows examples of calculation for the membership of B′.

For b_1,

$Min[\mu_A(a_1), \mu_R(a_1, b_1)]$
$=[0.4, 0.8]=0.4$

$Min[\mu_A(a_3), \mu_R(a_3, b_1)]$
$=[0.9, 0.3]=0.3$

$Max[0.4, 0.3]=0.4 \Rightarrow \mu_B(b_1)=0.4$

For b_2,

$Min[\mu_A(a_2), \mu_R(a_2, b_2)]$
$=[0.5, 0.2]=0.2$

$Min[\mu_A(a_4), \mu_R(a_4, b_2)]$
$=[0.6, 0.7]=0.6$

$Max[0.2, 0.6]=0.6 \Rightarrow \mu_B(b_1)=0.6$

For b_3,

$Max\ Min[\mu_A(a_4), \mu_R(a_4, b_3)]$
$=Max\ Min[0.6, 0.4]=0.4$
$\Rightarrow \mu_B(b_3)=0.4$

So fuzzy set B′ obtained by fuzzy set A and fuzzy relation R is,

$B'=[(b_1, 0.4), (b_2, 0.6), (b_3, 0.4)]$

Extension of fuzzy set and fuzzy relation is also possible among the several relations and sets. That is, the fuzziness in fuzzy set A can be propagated through more than one relations and sets.

Figure 4 Fuzzy set A can make a fuzzy set B′ in crisp set B by fuzzy relation $R_1 \subseteq A \times B$, and B′ again can make a fuzzy set C′ from fuzzy relation $R_2 \subseteq B \times C$.

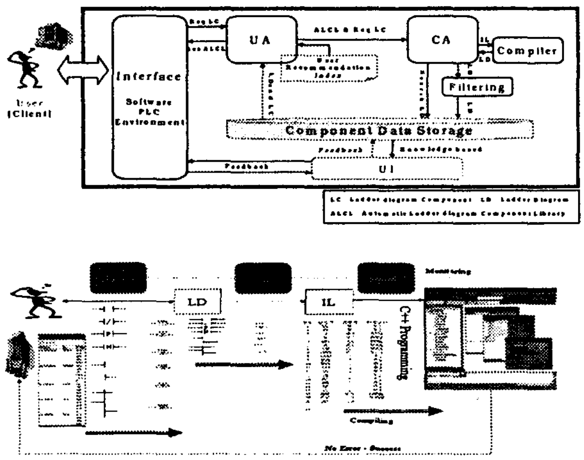


Fig. 4a. The overview of fuzzy traffic signal

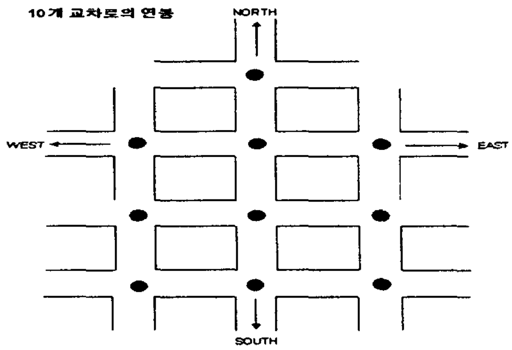


Fig.4 B Optimal traffic cycle of 10 Traffic intersection

In this section, we present a system for coordinating green time which controls 10 traffic intersections. For instance, if we have a baseball game at 8 pm today, traffic volume toward the baseball game will be increased 1 hour or 1 hour and 30 minutes before the baseball game. At that time we can not estimate optimal green time. Therefore, we used fuzzy neural network to estimate uncertain optimal green time and reduce vehicle waiting time. Fuzzy neural networks can accommodate uncertain traffic conditions very easily. In this paper, it antecedently creates an optimal traffic cycle of passenger car units at the bottom traffic intersection. Mistakes are possible due to different car lengths, car speed, and length of intersection. Therefore, it consequently reduces the car waiting time and start-up delay time using fuzzy control of feed-back data.

Moreover, to prevent spillback, it can adapt control even though upper traffic intersection has a different vehicle length, road slope and road width. Figure 5 shows a block diagram of an optimal traffic cycle light for 10 traffic intersection using fuzzy neural network and it can reduce vehicle waiting time and to determine optimal green time, adapting to any different type of traffic intersection. In order to solve spillback problems, we must determine which car is big or small. However, traffic intersection length, width of lane and number of lanes in the intersection is different. It adapts to the different traffic intersection types and sizes, while using the table 1.

In this paper, the neural network consist of one input layer, one hidden layer, and one output layer. We use supervised learning process which adjust weights to reduce the error between desired output and real output for green time. This is depicted as follows.

(1) Initialize Weights and Offset
(2) Establishment of training pattern
(3) Compute the error between target pattern output layer neural cell(t_j) and output layer neural cell(a_j)

$$e_j = t_j - a_j \qquad ①$$

(4) Calculate weights between input neural cell(i, j) by the following equation

$$W(new)_{ij} = W(old)_{ij} + ae_{ki} \qquad ②$$

$$e_j = t_j - a_j \qquad ③$$

(5) Repeat the process from number (2) above. The process is repeated until optimal green time is calculated.

In order to create optimal green time, it must consider different can lengths, length of traffic intersection and width of traffic intersection. If there are same waiting vehicle in the traffic intersection, we can not estimate offset and conversion factor of different traffic intersection. Therefore, we need adaptive fuzzy neural traffic control. Figure 5 shows explain how to create offset and optimal green time of different 20 traffic conditions.

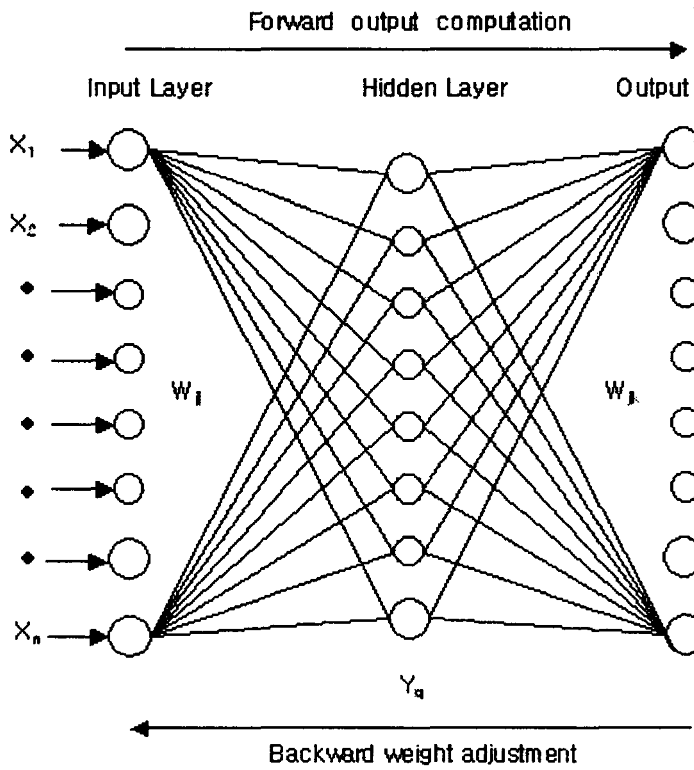
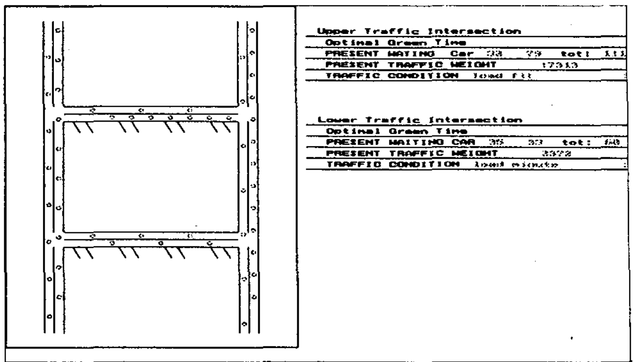


FIg. 5 Simulation of neural fuzzy neural traffic light

Table 3. Comparison with A.I. traffic light depending on different traffic intersection.



Switch on	Traffic condition								Passing car			Waiting time	
3 Roads	width of road			Length of road			Speed	Capacity	Big	Med	small	A.I. Light	T.O.D (Sec).
ABC	3	4	8	130	155	370	slow	High	5	4	7	52	60
CDE	4	4	6	170	140	390	med	High	4	9	8	55	60
ABC	4	6	8	190	320	250	slow	Med	2	0	4	48	60
EFG	8	4	6	250	190	140	G	High	2	3	13	51	60
ABC	4	6	8	150	190	120	B	Low	1	1	6	42	60
CDE	8	6	8	190	170	260	E	Low	3	2	5	39	60
ABC	4	4	6	250	230	280	A	Med	1	2	9	47	60
CDE	4	6	4	190	190	320	E	High	9	8	11	53	60

Fig 6. Simulation of A.I. traffic light depending on capacity of traffic intersection

5. Conclusion

In this paper, it proposed that we establish a safe priority order using fuzzy rules. Moreover to prevent spillback, it can adapt control itself when sensing upper traffic intersection and different saturation rate, road length, road slopes and road width, we can create optimal green time using fuzzy rules. Traffic congestion occurs on all road environments in one form or another. First there is the slow crawl along busy shopping street and construction work in the road, then the long queues that form when accidents occur on the roads, and the rapid, unpredictable slowing down and speeding up of traffic on overloaded in the traffic intersection.

Congested operations characterize the entire range of operations which may be experienced when traffic demand approaches or exceeds the road and junction capacity.

Thus, in this paper with the help of the fuzzy traffic network it allows the smooth run of traffic by repairing the state of traffic at 10 different intersections every 5 minutes and creating the minimum period of green signal based upon the amount of traffic.

Yet, the most efficient way is to control 10 different intersections with one traffic tower. Thus calculating the compensation variable of different road variables such as one-way streets and merging road conditions.

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