The Optimization of Traffic Signal Light using Artificial Intelligence

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Abstract

In the past, when there were few vehicles on the road, the T.O.D.(Time of Day) traffic signal worked very well. The T.O.D. signal operates on a preset signal cycling which cycles on the basis of the average number of average passenger cars in the memory device of an electric signal unit.

Nowadays, with increasing many vehicles on restricted roads, the conventional traffic light creates prove startup-delay time and end-lag-time. The conventional traffic light loses the function of optimal cycle. And so, 30-45% of conventional traffic cycle is not matched to the present traffic cycle. In this paper proposes electrosensitive traffic light using fuzzy look up table method which will reduce the average vehicle waiting time and improve average vehicle speed. Computer simulation results prove that reducing the average vehicle waiting time which proposed considering passing vehicle length for optimal traffic cycle is better than fixed signal method which dosen't consider vehicle length.

I . Introduction

After Dr. zadeh proposed the fuzzy theory and fuzzy logic, the application of the fuzzy set theory and fuzzy logic have been increased and widely used in many fields[3-4].

When there are few running vehicles, the signal cycle, should be shortened. In order to produce optimal signal cycle we must first check how many waiting cars are at the lower intersection, because waiting queue is bigger than the length of approach load, spillback occurrs and waiting queues occupy the intersection[1-2]. Also, offset decision in the traffic intersection becomes different at each signal by the waiting queue for the rest of the vehicles which don't pass the upper traffic intersection within green time among the vehicle that passed the lower traffic intersection. Therefore in this paper, we can create the optimal traffic signal using fuzzy control. Electro sensitive traffic light has a better efficiency than fixed preset traffic signal cycle because it is able to extend or shorten the signal cycle when the number of vehicles increase or decrease suddenly. Moreover, to prevent spillback and optimal traffic cycle, it can adapt control even though upper traffic intersection has a different vehicle length, road slope and road width. In this paper we used fuzzy membership function vary between 0 and 1 which estimate uncertain length of vehicle, vehicle speed and width of road. Fuzzy neural networks can accommodate uncertain traffic conditions very easily [5-6]. This paper is researching the storing of 40 different kinds of conditions. Such as, car speed, delay in starting time and the volume of cars in traffic. Through the use of a central nervous networking system or AI, using 10 different intersecting roads. We will improve the green traffic light. And allow more cars to easily flow through the intersections.

II . Vehicle waiting time

The mean volume of vehicles in the waiting line throughout the whole time is as follows.

$$Q = \frac{D}{C} = \frac{QR^2}{2C(1-Y)} \qquad (1)$$

$$D = \frac{D}{QC} = \frac{R^2}{2C(1-Y)} \qquad (2)$$

As for 'ALL SOP', when arriving traffic is not successive function but STEP FUNCTION that has the interval of mean 1/Q. Mean vehicle delay can be explain Eq. 3.

$$D = \frac{1}{2C(1-Y)}\left(R - \frac{1}{2S}\right) + \frac{Y(2-Y) + Q(1-Y)}{12Q} \qquad (3)$$

S : Congested traffic volume on one approaching road (PCU/second)
Q : Mean arriving traffic rate on one approaching road
C : Cycle length (second)
D : Mean vehicle delay per PCU on one approaching road (second)
R : Effective redlight time (second)
Y : Ratio of mean arriving rate to congested traffic volume Q/S

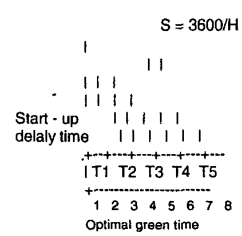

Fig. 1 Vehicle start up delay time depending on the number of vehicles

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Figure 1 shows 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. Moreover, in obtaining the optimal cycle with the existing signal light, as you can see from two kinds of roads, A and B, the width of crossroads, the length of crossroads, the volume of congested traffic, the gradient of road (Uphill Road, Downhill Road), the speed of moving vehicles and the like is different, so that you should find out the revision coefficient suggested by U.S. HIGHWAY CAPACITY MANUAL (HCM) to decide the signal cycle.

S = SO * FW * FHV * FC * FRT * FLT

S = Volume of congested traffic which is moving on one road by the same manifestation

SO = Volume of congested traffic of passenger cars

FW = Revision coefficient on Lane Width

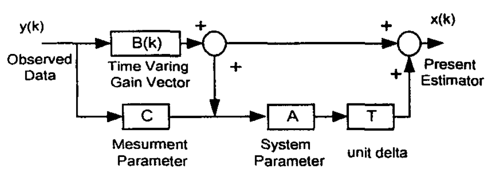
FHW = Revision Coefficient on Heavy vehicles

FC = Road Gradient and its Surface State

FRT = When turn to the right, exclusive signal, non-protecting signal and Distinction of permitted lane

FLT = When turn to the left, exclusive signal, non-protecting signal and distinction of permitted lane

The above formula, however, can be applied to a standard model, but on each road, A road and B road, the crossroad in the north south direction is different in the distance and at each crossroad the rate of congestion state is different, namely, the values of S and Q are different, so that we should consider START-UP DELAY TIME, END LAG TIME, transit vehicles, accumulated vehicles, speed of running vehicles to find out the optimal signal cycle. Even in case of the same rate of congestion state a conversion coefficient of passenger cars is different, so that the exact volume of running vehicles can't be estimated and the speed of running vehicles is changed by features of each crossroad, climate conditions and a rate of congestion state in its value, so that to remove these problems we need the artificial intelligence signal light of fuzzy rules and neural network that can manage vehicle flow to be smooth.



A = Transition matrix on System Equation

B = Transition Scala on Observation or Measurment Equation

Fig. 2 Kalman Filter Technique of traffic intersection

$$A = (1 - \beta) \times A(t) + \beta \times A(t-1) \quad (4)$$

$$A = A' + \text{Noise}$$
$$= (1-a) \times Exp(-bxT) + a \quad (5)$$

A = Real traffic vehicle data

β = Exponential Filter

A'= Underlying true traffic volume

As a result, the delay time of all cars on each road of the intersection during one cycle will be as follows;

$$D = D_{N\text{-}R} + D_{N\text{-}G} \quad (6)$$

$$D_{N\text{-}R} = \sum_{n2=1}^{n} (Q_G + \sum_{n1=1}^{n2} Q_{N1}) \quad (7)$$

$$D_{N\text{-}G} = \sum_{n2=1}^{n} (Q_R + \sum_{n1=1}^{n2} Q_{N1} - S_N) \quad (8)$$

Conventional traffic signal system cause vehicle waiting time, reduce average running speed. Because this system has no function to extending, or reducing signal period by sudden vehicle stream. Optimal signal period is studied by using Kalman filter method and fuzzy rule for deciding optimal offset as to preventing spillback phenomenon and to reducing vehicle waiting time. In fig. 2 predicate method of signal period has demerits by Kalman filter method that algorithm is not modeled always correctly. This paper is studied by using neural network and 27 fuzzy rules as to preventing weak spillback phenomenon of highsaturation in ordinary fixed signal period method.

III Optimal green time

Overflow is defined in the period of i-1 as Q_{i-1}, the length of waiting vehicles in the end point of red time is found by summing the value of multiplying arriving rate by red time(r) to Q_{i-1}. When red time starts waiting vehicles outflow to saturated traffic rates and the starting wave created by the start of green time is transferred to the back as the velocity,w. During that time , arriving vehicle continue to the tail of stopping and waiting vehicles. After green time starts, green time starting wave reaches to the tail of waiting vehicles, then stopping and waiting vehicles is gone and all vehicles on the link get moved.

The maximum length of waiting vehicle is defined as the number of stopping vehicles from stopping line to the point of the last stopping vehicle. If it is called the maximum length of waiting vehicles as MAXQi, by arriving rate

$$MAXQ_i = Q_{i-1} + v \cdot (r+t) \quad (9)$$

where,

Qi-1 : the length of waiting vehicles in the end point in period i-1

v : arriving rate

r : red time

t : lap time of red time by start and velocity

$$MAXQi = w \cdot t \quad (10)$$

where,

w : starting wave caused by green time overflowing to saturated traffic rate

t : lap time of green time

from eq. (8) and eq. (9)

$$t=(Q_{i+1}+v\cdot r)/(w-v)N \qquad (11)$$

$$MAXQ_i=Q_{i-1}+v[r+(Q_{i-1}+v\cdot r)/(w-v)] \qquad (12)$$

where,

w : starting wave caused by green time overflowing to saturated traffic rate

v : arriving rate

or

$$MAXQ=w\cdot(Q_{i-1}+v\cdot r)/(w-v) \qquad (13)$$

We can estimate the maximum length of waiting vehicles when understanding all the overflow at the period starting point and velocity caused by green time arriving rate, saturated overflow. But in signal control system the information about the length of waiting vehicles is limited at the past information then it must be estimated the length of waiting vehicles.

Therefore, we must evaluate model that estimate the maximum length of waiting vehicles obtained from real traffic conditions. If it is called the evaluated the maximum length of waiting vehicles in period i-1 and period i as $MAXQ_{i-1}$, $MAXQ_i$, arriving rate v_i is obtained as the following.

$$Q_{i-1}=MAXQ_{i-1}+(g-t)\cdot v_i-s\cdot g \qquad (14)$$

If maximum waiting queue is measured in each period, arrival rate is determined corresponding to the period. The accurate arrival rate is not estimated in each period, because of irregular traffic quantity. Therefore the next period arrival rate is estimated with previous arrival rate smoothing. Moving average of previous 3 period is obtained with next period arrival rate. So, estimated arrival rate in next period is :

{ FV_i+1 = { V_i-2 + V_i-1 + V_i } over 3} (15)

Where,

MAXQrm Q_i-1 : measured waiting queue length of (i-1) period

MAXQrm Q_i : measured waiting queue length of i period

Vi : arrival rate

The offset obtained from maximum waiting queue that is minimized slow and stop time, when the car go on from precedence cross-road to subordinary cross-road. But, waiting queue by vehicle change coefficient is not regular in actual traffic situation. Optimal offset is not obtained easily, because start wave velocity is different from every periods.

IV. Design of optimal fuzzy traffic cycle

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 greentime. 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. 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 fuzzy 27 rules.

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(tj) and output layer neural cell(aj)

$$e_j = t_j - a_j \qquad (16)$$

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

$$W(new)_{ij} = W(old)_{ij} + \alpha\ e_{iaj} \qquad (17)$$

$$e_j = t_j - a_j \qquad (18)$$

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

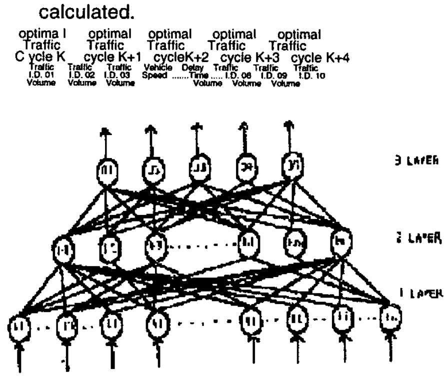


Fig. 3 Simulation of neural fuzzy neural traffic light

Figure 3 shows neural network to estimate uncertain optimal green time and reduce vehicle waiting time.

In order to improve vehicle waiting time, we used a 3 input fuzzy membership function and 2 output fuzzy membership function. The following is the Fuzzy Logic Control of the

Traffic Signal Light. On the basis of 'RULE BASE' of 'FUZZY MEMBERSHIP' function under each condition, we use the MAX-MIN deduction method and the center of gravity method as Defuzzification method

High saturation rate (Upper Traffic intersection)

IF PA is Low and PS is MED
and WT is High then
Op is HIGH, Os is Low

PA is Degree of saturation rate
PS is Passing vehicle speed
WT is Length of vehicle vehicle
OP is Expecting Traffic signal cycle
OS is Expecting strtup delayTime

Optimal traffic cycle= Expecting car speed(OS) * Number of cars * Expecting passenger car unit(op)

Table 1 explains the adaption of optimal green time control, even though the upper traffic intersection has a different vehicle length, road slope and road width.

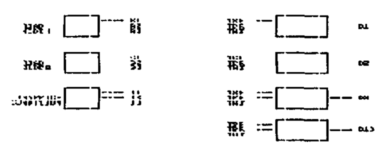
Table 1 Adapting fuzzy rule for length of vehicle and width of road

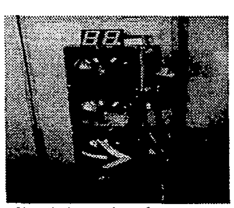
ROAD CAR	RWDH	RWDM	RWDS
PCUH	M	B	PB
PCUM	S	M	B
PCUS	S	S	M

RWDH : width of road is high
PCUB:Vehicle length is high
RWDM: width of road is medium
PCUM:Vehicle length is medium
RWDS:width of road is small
PCUS:Vehicle length is small

	INPUT			OUTPUT	
	TSP	TPR	TWT	OP	OS
0000	1-20	1-30	400-1000	1.5	3.0
0001	1-20	31-60	400-1000	1.3	3.0
0101	1-20	61-100	400-1000	1.2	2.8
0110	41-60	1-30	400-1000	1.5	3.0
:	:	:	:	:	:
11000	41-60	1-30	2001-4000	1.7	3.0
11001	41-60	31-60	2001-4000	1.6	3.2
11010	41-60	61-100	2001-4000	1.9	3.5

BLOCK1





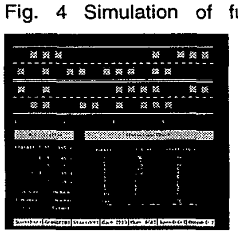


Fig. 4 Simulation of fuzzy traffic light using fuzzy look up table

V . Conclusion

The fuzzy traffic controller shows reducing waiting time at the high saturated traffic condition. But in case of low saturated traffic condition, there are a little bit difference for reducing waiting time with vehicle waiting time of fuzzy traffic light and conventional traffic light. Finally, the proposed A.I. traffic simulation controller system has been implemented using look up table method and tested with various types of traffic condition as shown in fig.4 and fig.5. For the fuzzy controller, the average waiting time decreased by 15 percent when compared with the conventional controller. The fuzzy controller simulation was compared with waiting time of T.O.D. signal light and fuzzy traffic light. In this paper, we can determine passenger car unit using 3 fuzzy membership and 27 fuzzy logic control rules. It proved that it can get the better results than the conventional signal don't have passenger car unit and offset. Finally, computer simulation confirms that vehicle waiting time gets improved by 10-15% even in case of spillback or large vehicles' sudden entry.

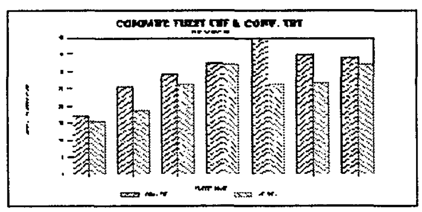


Fig. 5 Comparisons between fuzzy traffic light waiting time for high saturation conventional traffic light

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