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Optimal Traffic Information using Fuzzy Neural Network

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Abstract

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. Now days, 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 electro sensitive 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.

Key words : Vehicle waiting time, Fuzzy lookup table hardware, Optimal green time

1. Introduction

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 occurs and waiting queues occupy the intersection[1-5]. 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 [6-7].

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 [8-11].

This paper is researching the storing of 20 different kinds of conditions. Such as, car speed, delay in starting time and the volume of cars in traffic.

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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.

In the section Ⅱ, we will discuss the protection of traffic stoppage, the smooth flow of cars and car waiting time.

Section Ⅲ, we will explain how many cars passes through each intersection and revising how to calculate the AI and produce better light time at each traffic stop and control the volume of cars.

Section Ⅳ, we describe determination of optimal traffic cycle using neural network and fuzzy logic computer simulations. The optimal traffic system will recognize the present time situation within 1 minute.

Finally Section V will give conclusions. This will allow the green light to affect 10 intersections using one central nervous system network.

2. Vehicle waiting time

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

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

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

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

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

where,

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 red light time (second)
Y : Ratio of mean arriving rate to congested traffic volume Q/S

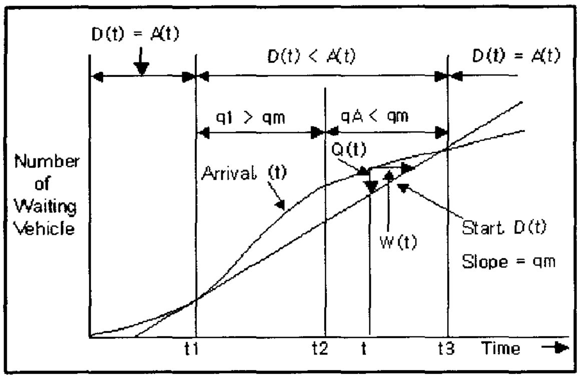


Fig. 1 Vehicle start up delay time depending on the number of vehicles

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.

Figure 1 explains a waiting line from T1 TO T3 .

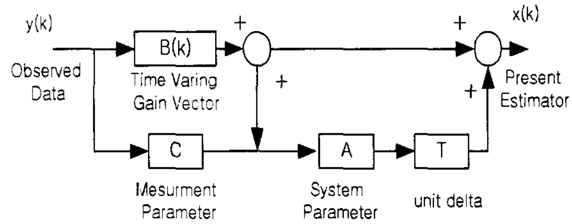
A moment T within T1 and T3 has a waiting line length, Q(T)=A(T)−D(T). The perpendicular arrow (QT) indicates the volume of vehicles accumulated after the red light turns on, and the horizontal arrow(WT) the time for which a vehicle arrives and departs. Therefore the vehicle that arrives after T second can depart after W(T). The whole waiting time is the area between the curves of arrival and depature and the length of waiting line is highest at T2 when the arrival rate is the same as QM.

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.

$$S=SO\times FW\times FHV\times FC\times FRT\times FLT \quad (4)$$

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

$$\begin{aligned} A &= (1-\beta)\times A(t)+\beta\times A(t-1) \\ &= A'+Noise \\ &= (1-a)\times \mathrm{Exp}(-b\times T)+a \end{aligned} \quad (5)$$

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;

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 high saturation in ordinary fixed signal period method. The decision schema analytic hierarchy process is shown below.

3. 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, 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.

$$MAXQ_i = Q_{i-1} + v(r+t) \quad (6)$$

where,
Q_{i-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

$$MAXQ_i = w \times t \quad (7)$$

where,
w : starting wave caused by green time overflowing to saturated traffic rate
t : lap time of green time
from eq. (6) and eq. (7)

$$t = (Q_{i-1} + v \times r)/(w-v)N \quad (8)$$

$$MAXQ_i = (Q_{i-1} + v[r + (Q_{i-1} + v \times r)/(w-v)] \quad (9)$$

where,
w : starting wave caused by green time overflowing to saturated traffic rate
v : arriving rate
or

$$MAXQ = w \times (Q_{i-1} + v \times r)/(w-v)] \quad (10)$$

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 $MAXQ_{i-1}$, MAXQi, arriving rate vi is obtained as the following.

$$Q_{i-1} = MAXQ_{i-1} + (g-t) \times v_i - s \times g \quad (11)$$

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 :

$$FV_{i+1} = \frac{V_{i-2} + V_{i-1} + V_i}{3} \quad (12)$$

where,
MAXQ Q_{i-1} : measured waiting queue length of $(i-1)$ period
MAXQ 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. Figure 3 explains how to create optimal green time, offset, red interval and waiting queue depending on different length of lower and upper traffic intersection.

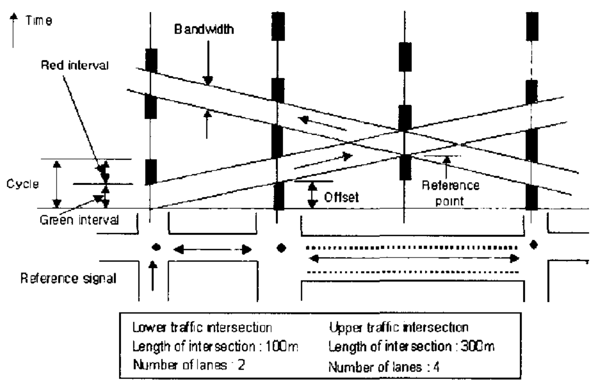


Fig 3. Optimal green time depending on lower and upper traffic intersection

4. 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. Figure 4 shows a block diagram of an optimal traffic cycle light, 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 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)

$$e_j = t_j - a_j \qquad ①$$

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

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

$$e_j = t_j - a_j \qquad ③$$

(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. Figure 5 shows how to create optimal green time using fuzzy neural network.

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 6 shows explain how to create offset and conversion factor of traffic condition.

In order to improve vehicle waiting time and 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.

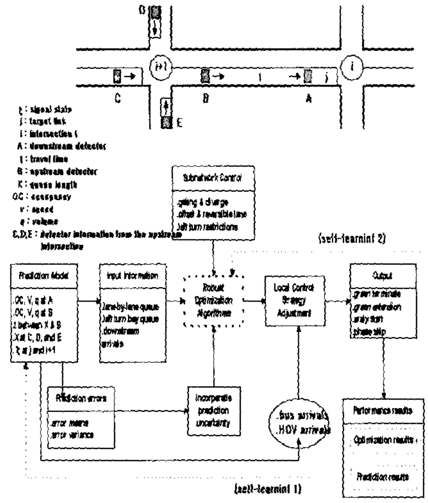


Fig. 4 Block diagram of fuzzy neural traffic light

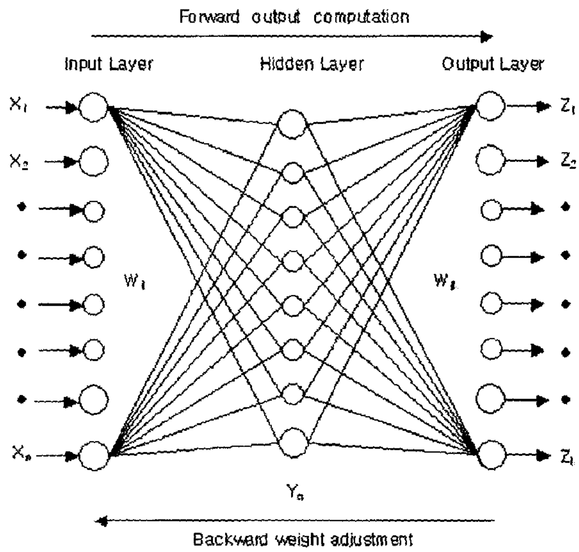


Fig. 5 Simulation of neural fuzzy neural traffic light

$$\mu_{CE}(ce) = \begin{cases} 0, & \text{if } ce \le \beta - \gamma_L \\ \frac{1}{2}\left[2\left(1+\frac{ce-\beta}{\gamma_L}\right)\right]^{\lambda+1}, & \text{if } \beta - \gamma_L \le ce \le \beta - \gamma_L/2 \\ 1+\frac{1}{2}\left[\frac{2(ce-\beta)}{\gamma_L}\right]^{\lambda+1}, & \text{if } \beta - \gamma_L/2 \le ce \le \beta \\ 1+\frac{1}{2}\left[\frac{2(ce-\beta)}{\gamma_R}\right]^{\lambda+1}, & \text{if } \beta \le ce \le \beta + \gamma_R/2 \\ \frac{1}{2}\left[2\left(1+\frac{ce-\beta}{\gamma_R}\right)\right]^{\lambda+1}, & \text{if } \beta + \gamma_R/2 \le ce \le \beta + \gamma_R \\ 0, & \text{if } ce \ge \beta - \gamma_R \end{cases}$$

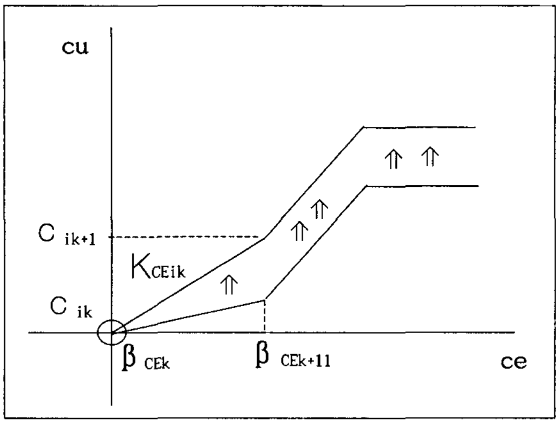


Fig. 6. Change in error recalculaton depending on number of lane

Table 1 shows 20 input data for creating a fuzzy neural traffic light. Table 2 shows optimal green time when there are different length of intersection and number of vehicles.

Table1. Input data for fuzzy neural traffic light

Green time / INPUT	NODE 1-2 REDUCE	NODE 1-2 EXTENSION	NODE 3-4 REDUCE	NODE 3-4 EXTENSION	NODE 5-6 REDUCE	NODE 5-6 EXTENSION	NODE 7-8 REDUCE	NODE 7-8 EXTENSION	NODE 9-10 REDUCE	NODE 9-10 EXTENSION
1. SATURATION UP BIG	BIG	SMALL	MED	SMALL	BIG	SMALL	BIG	SMALL	BIG	SMALL
2. SATURATION UP SMALL	BIG	SMALL	BIG	SMALL	MED	SMALL	BIG	SMALL	BIG	MED
3. PASSING UP SMALL	SMALL	SMALL	BIG	SMALL	BIG	MED	BIG	SMALL	BIG	SMALL
4. PASSING UP SMALL	BIG	MED	BIG	MED	MED	SMALL	BIG	MED	BIG	SMALL
5. SATURATION DN SMALL	BIG	SMALL	MED	SMALL	BIG	MED	BIG	SMALL	BIG	MED
6. SATURATION DN BIG	SMALL	SMALL	BIG	SMALL	BIG	SMALL	BIG	SMALL	BIG	SMALL
7. PASSING DN SMALL	BIG	MED	BIG	MED	MED	SMALL	BIG	MED	BIG	SMALL
8. PASSING DN BIG	SMALL	BIG	MED	SMALL	BIG	MED	BIG	SMALL	BIG	MED
9. PASSING PCU	MED	SMALL	BIG	BIG	BIG	SMALL	BIG	SMALL	BIG	SMALL
10. SPEED & LENGTH DN	MED	MED	BIG	SMALL	MED	SMALL	BIG	MED	BIG	SMALL
11. SPEED & LENGTH UP	MED	SMALL	BIG	SMALL	BIG	MED	BIG	SMALL	BIG	MED
12. SPILLBACK DOWN	MED	SMALL	BIG	SMALL	BIG	SMALL	BIG	SMALL	BIG	SMALL
13. SPILLABCK UP	BIG	SMALL	BIG	SMALL	BIG	SMALL	MED	SMALL	BIG	SMALL
14. DELAY UP	LOW	HIGH	MED	SMALL	MED	SMALL	MED	MED	MED	SMALL
15. DELAY DN	BIG	SMALL	BIG	SMALL	MED	SMALL	BIG	SMALL	MED	MED
16.LANES UP	BIG	SMALL	BIG	SMALL	BIG	SMALL	BIG	SMALL	BIG	SMALL
17.LANES DN	MED	BIG	MED	MED	MED	MED	MED	MED	MED	
18.BLOCK AREA	SMALL	SMALL	SMALL	SMALL	MED	SMALL	MED	SMALL	MED	SMALL
19.PHASE-1 UP	SMALL	BIG	MED	SMALL	MED	SMALL	MED	SMALL	MED	SMALL
20.PHASE-1 DN	BIG	BIG	BIG	MED	BIG	MED	BIG	MED	MED	MED

Table 2. Optimal green time depending on different traffic intersection

	①				②			③			Time
	R	Y	A	G	R	Y	A	R	Y	G	(second)
1				●	●					●	40
2					●						3
3	●				●		●	●			20
:								●			3
9			●	●	●			●			35
10					●			●			3

It is very difficult to produce the proper periodic signal and minimum car waiting time. Because the same intersecting roads, length of intersecting roads, speed of car, amount of road lines and straight or rotating car lines must be changed and produce the proper periodic signal to allow easier flow of traffic as shown in figure 7. Optimal green time using fuzzy neural network algorithm is given as follows.

(1) First decide 10 different intersections into 3 by 3 amount and analyze traffic level, accumulated number of vehicles waiting.
(2) In order to analyze the current passing traffic creating the minimum period of green of green signal by calculating check-in direction 1 traffic and traffic of checkout direction 2 is necessary. But, the number of vehicles is too hard to predict for such a large amount of possible cars.
(3) To create the minimum amount of green signal shape of intersections and waiting time of vehicles are considered and used keeping constant information.
(4) If the higher and lower detectors of the intersection are both reading, on and the accumulated number of vehicles is on, high the intersections is overloaded with cars. Thus, after calculating of each intersection, save this information in the intersection database.
(5) Calculate the minimum period of green signal by using predicted traffic amount operation and predicted passing time. Examine the shortest route algorithm
(6) Most lights blink the yellow light for at least 3-5 seconds most drivers are confused by this and don't know how to react to this situation. This article we will discuss how to prevent this situation by placing the amount of time remaining of the green light. Also we will display the level and amount of time left in the red light.

GT1 = NVEH * 3 + CFLane + Strating Delay Time + End lagtime

LostTmeG1 = Green − 1(1/3 Pg) + Yellowtime(Pg + 1/2 Py) + Redtime(Pg+Py + 1/3 r)

GT2 = NVEH * 3 * + Starting Delay Time

LostTmeG2 = Green − 1(1/21Pg) + Yellowtime(Pg + 1/2Py) + Redtime(Pg + Py + 1/2Pr)

GT3 = NVEH * 3 * CFLane + Starting Delay Time + Road conversion Time

LostTmeG3 = Green − 1(Pg) + Yellowtime(Pg + 1/2Py) + Redtime (Pg + Py + 1/2Pr)

GT4=NVEH * 3 + Delay Time

LostTmeG3 = Green − 1(1/4 Pg) + Yellowtime(Pg + 1/4Py) + Redtime(Pg + Py + 1/4 Pr)

GT5 = NVEH * 3 * CFLane + Starting Delay Time + Road conversion Time

LostTmeG3 = Green − 1(1/4 Pg) + Yellowtime(1/3 Pg + 1/4 Py) + Redtime(1/3Pg + Py + 1/4 Pr)

where:

GT1, Gt2..Gt5 : Optimal Green Time

NVEH : Number of Vehicles
CFLane : Converssion factor of Lane
Starting Delay Time:
Road conversion Time:
PG : Probability of Green Time
PY : Probability of Yellow Time
PR : Probability of Red Time

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

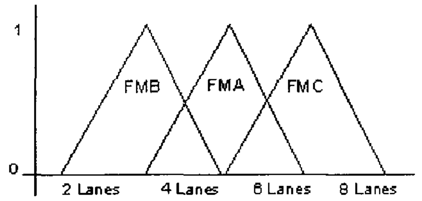


Fig 7. Adaptive fuzzy control depending on number of lane

According to the simulation, over 25 to 38% of traffic waiting time is reduced as shown in figure 8. Figure 9 shows that vehicle waiting time and average vehicle speed gets improved 20~30%.

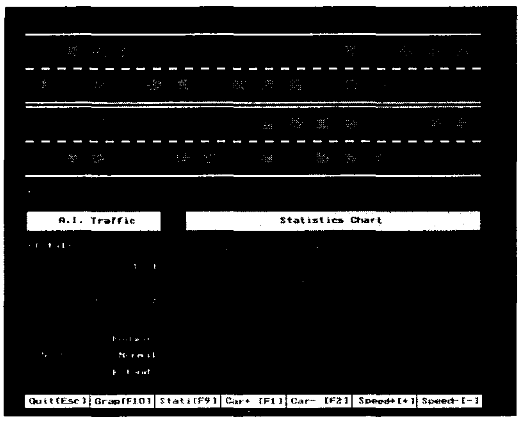


Fig 8. Simulation of fuzzy traffic light

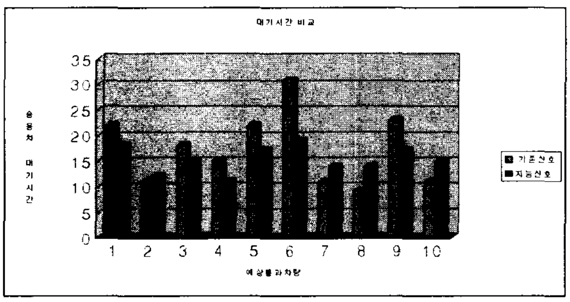


Fig 9. Comparisons between fuzzy traffic light waiting time for high saturation conventional traffic light

5. 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.

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.

No matter how well the electric traffic light has been systematized, it cannot properly function during a department stores sudden sale period, holidays or traffic over runs at 130%.

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.

According to the simulation, over 25 to 38 % of traffic waiting time is reduced.

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