論文
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Artificial Traffic Signal Light using Fuzzy Rules

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Abstract

The conventional traffic light loses the function of optimal traffic signal cycle. And so, 30-45% of conventional traffic signal cycle is not matched to the present traffic signal cycle. In this paper proposes electro sensitive traffic light using fuzzy rules which will reduce the average vehicle waiting time and improve average vehicle speed.
This paper is researching the storing method of 40 different kinds of sensor input conditions. Such as, car speed, delay in starting time and the volume of cars in the real traffic situation. It will estimate the optimal green time in the 10 different intersections using intelligent fuzzy method. Computer simulation results prove that reducing the average vehicle waiting time and offset better than fixed signal method which doesn't consider vehicle length.
Keyword : Vehicle waiting time, Fuzzy lookup table hardware, Optimal green time

요 약

기존 교통신호등은 최적 교통신호주기기능을 상실했다. 기존 교통신호주기는 현시 교통주기와 30% -45% 가 일치하지 않고 있다. 본 논문에서는 평균 주행속도를 개선하고 평균 승용차 대기시간을 단축하기위해서 전자 교통신호등을 본 논문에서 제안한다. 본 논문에서는 실제 교통상황의 교통량, 출발 지연시간, 자동차속도 등의 40가지 센서 입력조건들을 저장하는 방법을 연구 중이다.
지능형 퍼지 기법을 이용하면, 서로 다른 10개의 교차로에서 최적의 녹색시간을 예측할 수 있다. 컴퓨터 모의실험 결과, 자동차 길이를 고려하지 않은 기존 교통신호등보다 , 오프셋 및 평균 자동차 대기시간을 줄일 수 있음이 입증되었다.

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I. INTRODUCTION

When there arefew 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[1-3]. 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 [9-10].

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 differentvehicle length, road slope and road width. In this paper we used fuzzy membership function vary between 0 and 1 which estimate uncertainlength of vehicle, vehicle speed and width of road. Fuzzy neural networks can accommodate uncertain traffic conditions very easily [7-12].

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. 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. This dissertation 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.

In the section ?, we will discuss the protection of traffic stoppage, the smooth flow of cars and car waiting time. Section ?, 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 ?, 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 ? will give conclusions. This will allow the green light to affect 10 intersections using one central nervous system network.

II. VEHICLE WAITING TIME

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. 1.

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

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

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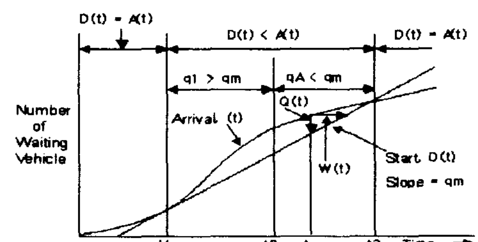
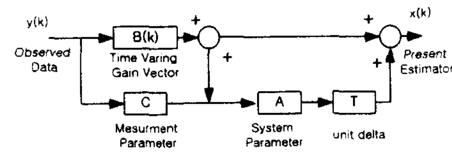


Figure 1. Vehicle start up delay time depending on the number of vehicles

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 T1TOT3 . A moment T within T1 andT3 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 departure 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.

However, 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 aredifferent, 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

Figure. 2Kalman filter technique of traffic intersection

$$A = (1-\beta)\times A(t) + \beta \times A(t-1)$$
$$= A' + Noise$$
$$= (1-\alpha)\times Exp(-b\times T) + a \qquad (2)$$

where,
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 Figure 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.

IV. OPTIMAL GREE TIME

Overflow is defined in the period of i-1 as Qi-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 Qi-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.

$$MaxQ_i = Q_{i-1} + v(r+t) \qquad (3)$$

where, Qi-1 : the length of waiting vehicles in the endin period i-1

v : arriving rate

r : red time

t : lap time of red time by start and velocity

We can estimate the maximum length of waiting vehicles when understanding allthe 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 islimited 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 MAXQi-1, MAXQi, arriving rate vi is obtained as the following.

$$Q_{i-1} = MaxQ_{i-1} + (g-t) \times v_i - s \times g \qquad (4)$$

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

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.

Figure 3. Optimal green time depending

onand upper traffic intersection

Ⅳ. DESIGN OF OPTIMAL FUZZY TRAFFIC CYCLE

A. Optimal Green Time

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 differentvehicle 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 andnumber of lanes in the intersection is different.It adapts to the differenttraffic intersection types and sizes, while using the fuzzy 27 rules.

In this paper, the neural network consistsof 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 oftraining pattern

(3) Compute the error between target pattern output layer neural cell(tj) andoutput layer neural cell(aj)

$$e_j = t_j - a_j \tag{5}$$

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

$$w(new)_{ij} = w(old)_{ij} + ae_{iaj} \tag{6}$$

$$e_j = t_j - a_j$$

(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 canlengths, length of traffic intersection and width of traffic intersection. Figure 4 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 neuraltraffic control. Figure 6 shows the simulation of neural fuzzy neural traffic light.

In order to improve vehicle waiting time and vehicle waiting time, we used a 3 inputfuzzy 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 new MAX-MIN CRI method in section B.

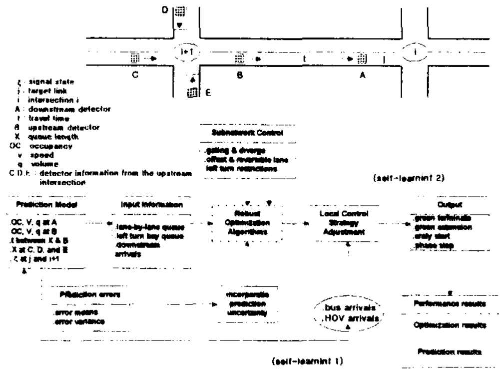


Figure 4. Block diagram of fuzzy neural traffic light

Figure 5. Simulation of neural fuzzy neural traffic light

B. New MAX-MIN CRI Method

The traditional Max-Min CRI method results in considerable error regions. To overcome those problems, we adopt the New Max-Min CRI method[16]. The new Max-Min CRI method has an additional process which compute a similarity degree by a new similarity measure, and apply it to the inference process of the Max-Min CRI method. Most papers have discussed the above similarity measure in too general points of view. A similarity measure needs not to have generality but to have specialty according to domain area and inference methods. The above mentioned similarity measures can't apply to the Max-Min CRI method, because they can't be guaranteed except estimating of language similarities. Also, as the measuring equation is too complicated, much simpler measure should be proposed in real time system.

Therefore, to overcome some problems of the Max-Min CRI method in real time, a New Max-Min CRI inference method, which is called NCRI(New Max-Min CRI) method, is proposed . In the NCRI method, the similarities between fuzzy sets are estimated by the proposed similarity measure, and the remaining process follows the Max-Min CRI method. As a result, the error regions which are occurred in the Max-Min CRI method can be decreased to acceptance range.

The proposed similarity measure is described as the following Definition 4.1.

Definition 4.1 Similarity Measure

For all $u \in U$, the similarity degree between two fuzzy sets is determined by the following equation. In here, τ is a measured similarity degree or value, ' $\wedge$ ' means '**min**' and ' $\vee$ ' means '**max**' operation.

$$SM(A, A') = \tau = \frac{\int(\mu_A(u) \wedge \mu_A'(u))du}{\int(\mu_A(u) \vee \mu_A'(u))du}, \quad for \quad all \quad u \in U$$

The meaning of the equation is in Figure 6. For all universe of discourse ($u \in U$), the shadowed part is the intersection part of two fuzzy sets and the white part is the union part of two fuzzy sets.

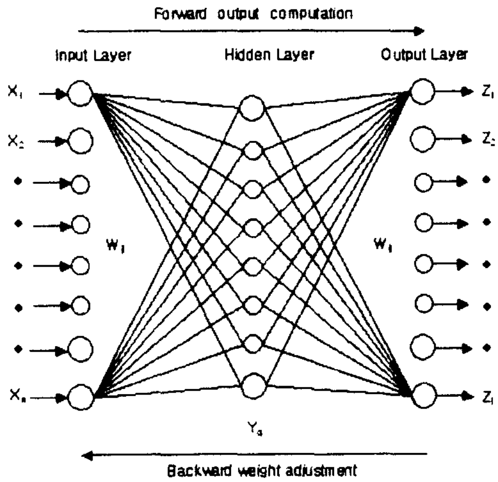


Figure 6. Similarity measure in NCRI

The NCRI algorithm having the proposed similarity measure consists of three necessary procedures: fuzzification procedure, inference procedure, and defuzzification procedure .

(1) Fuzzification Procedure

The fuzzification membership functions in a fuzzy rule base are triangular typed ones defined by equation (7) with $a,b,u \in U$. The fuzzy rule base composes of MISO(Multy Input Single Output) typed rule base. Each fuzzy membership function in a fuzzy rule base has a membership value area $[0,1]$, and should be normalized in this area.

$$y = \begin{cases} \frac{2}{b-a}(x-a), & a \le u \le b, \quad u \in U \\ 0, & otherwise \end{cases} \qquad (7)$$

This interval includes all possible values for the variable in universe of discourse (U). All fuzzy sets in a fuzzy rule base have the same support interval $[a,b]$. The equation can be represented all types of fuzzy membership functions both fuzzy and non-fuzzy membership functions.

(2) Inference Procedure

The main process of NCRI is the following equation. Compare to the Max-Min CRI method, NCRI makes use of the proposed similarity measure in **Definition 4.1** between input facts and fuzzy sets in a condition part(antecedent) of a rule. The similarity degree which is estimated by the similarity measure is represented as τ in (8). For all rule i, the following steps are performed for inference.

$$\begin{aligned} \mu_{B'}(v) &= \underset{u \in U, v \in V}{Max}\, Min(\mu_{A'}(u), \mu_R(u,v)) \\ &= \underset{u \in U, v \in V}{Min}\,(Max\, Min(\mu_{A'}(u), \mu_A(u)) \times \tau, \mu_B(v)) \\ &= \underset{u \in U, v \in V}{Min}\,(\alpha \times \tau, \mu_B(v)) \end{aligned} \qquad (8)$$

(3) Defuzzification Procedure

In defuzzification procedure of NCRI method, for the '$ALSO$' operation, '**max** 'operation is adopted as the Max-Min CRImethod. From the results of equation, the defuzzification procedure can be activated by the following quation.

$$\mu_B = \underset{v \in V}{Max}\, \mu_{Bi}'(v), \quad for \quad all \quad rule\ i, \quad 0 \le i \le n \qquad (9)$$

And then, the center of gravity method is adopted for producing the defuzzified value.

$$Defuzzification\ value = \frac{\int \mu_B(v) \cdot v dv}{\int \mu_B(v) dv} \qquad (10)$$

We use 20 input data for creating a fuzzy neural traffic

light. 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 fuzzyneural network algorithm is given as follows.

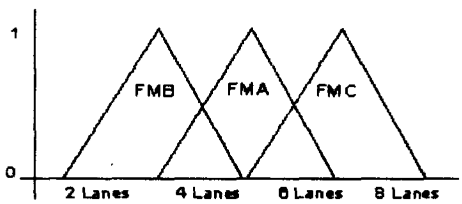


Figure 7. Adaptive fuzzy control depending on number of lane

a)decide 10 different intersections into 3 by 3 amount and analyze traffic level, accumulated number of vehicles waiting.

b)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.

c)To create the minimum amount of green signal shape of intersections and waiting time of vehicles are considered and used keeping constant information.

d)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.

e)the minimum period of green signal by usingpredicted traffic amount operation and predicted passing time. Examine the shortest route algorithm

f)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.

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

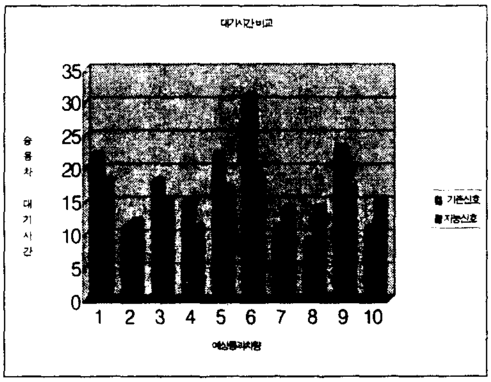


Figure 8. Comparisons between fuzzy traffic light waiting timehigh saturation conventional traffic light

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 vehiclewaiting 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 ofT.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 orlarge 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 Sense 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. Also this system analyzes one week of proposed traffic situations and describes the different intersections and provides information on local businesses such as gas stations and restaurants. It could provide the best road-traffic service to the driver.

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