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Design of Prevention Spillback Algoiithm using Fuzzy Rule

* Hong, Yousik, ** Cho, Hyungki, *** Park, Chongkug

* Dep. of Computer Science Sangji Universsity, Wosandong, Wonju, Kangwondo, KOREA
Tel : 82-371-42-1121 Fax:82-371-45-2433 Emal:h5674@chollian.dacom.co.kr
** Dep. of Transportation Englneering AJou Universsity, Swon, KOREA
Tel : 82-331-219-2543 Fax:82-33-215-7604
*** Dep. of Electronics KyungHee University, Swon, Kyungkido, KOREA
Tel : 82-331-280-2523 Fax:82-331-281-4968

Abstract:

Traffic signal cycle optimization is one of the most efficient ways for reducing fuel consumption and improving vehicle wating time of highsaturated traffic conditions. But, most research focused on lowsaturated traffic conditions. Only a few studies have researched traffic control for highsaturated traffic conditions. In this paper reviews the problem of conventional traffic signal system and creates optimal traffic cycle of at the bottom traffic intersection using 27 fuzzy rules. Moreover, to prevent spillback, it can adapt control even though upper traffic intersection has a different saturation rate, road length, road slope and road width.

I. Introduction

Thesedays, the role of the traffic signal is very important when the volume of traffic can't be predicted. It is when there are a lot of running vehicles at a crossroad, the signal cycle should be extended and when there are a few running vehicles, the signal cycle should be shortened. Most research focused on lowsaturated traffic conditions [1,2,3,4]. Only a few studies have researched traffic control for highsaturated traffic conditions [6,7]. In order to produce traffic optimal signal cycle we must first check how many waiting cars are in the lower intersection. If there are a lot of passing cars from the upper intersection, there will not be enough space. T.O.D. traffic signal system only repeat the fixed preset traffic signal cycle. so, it makes end lag time and start lost time when Measurements of queue length for expecting vehicle of lower traffic intersection is bigger than capacity of upper traffic intersection. Therefore in this paper, to prevent spillback of highsaturated traffic conditions, it can create the optimal traffic signal using fuzzy control. That is the advantage to the fuzzy traffic signal system. Even when a congestion rate of accumulated vegicles keeps the vehicles from moving ah the upper intersection, the conventional signal maintains the preseet traffic signal cycle. also when there is a high scaturation of waiting cars cans and cars cannot pass anymore, conventional signal lighs, through maintaining a fixed preset traffic signal cysle, cause END LAG TIME and at the next signal bring a loss of time due to START-UP LOST TIME. In other words, in addtion to the amount of passing cars the traffis backup gets worse and the danger of traffic accidents follows. If we improve average traffic speed by 10-15%, It will save 2 million dollars per year. In order to get an optimal traffic signal cycle in the intersection, We can determine passenger car units using fuzzy membership. Currently, studies are underway to shorten the average wating time of spillback occuring in an oversaturated situation under the present signal system by shortening or extending the signal time using loop detectors, micro wave detectors and image processing detectors. In this paper, it creates optimal traffic cycle of passenger car unit at the bottom traffic intersection unsing 27 fuzzy rules. BUt, sometimes it can makes due to changes in car weight and car speed. Therefore, it adjust output fuzzy membership function even though upper traffic intersection conditions have different saturation rate, road length, road slope and road width. Vehicle waiting time of computer simulation results are also compared with T.O.D. traffic signal system and fuzzy traffic system.

2. Method of determining optimal cycle

As you can see from Fig 1. there are 6 vehicles wating for lower traffic intersection and three are low saturated traffic condition in the upper traffic intersection. In this case, degree of saturation for upper traffic intersection is low, it can pass 6 vehicles to upper traffic intersection in the green time. But, Fig 2. shows spilback of upper traffic intersection. In this case there are degree of saturation for upper traffic intersection is low, it can pass only 4 vehicles to upper traffic intersection is low, it can pass 6 vehicles to upper traffic intersection in the green time. But, Fig 2. shows spillback of upper traffic intersection. In this case there are degree of saturation for upper traffic intersection is low, it can pass only 4 vehicles to upper traffic intersection in the green time. Because, In Fig 1. waiting vehicle consists of 4 small vehicles and 2 medium vehicles. So, it can pass 6 vehicle to upper traffic intersection in the green time. In Fig 2. waiting vehicle consists consisting of 3 large vehicles and 3 medium vehicles. So, it can pass only 3 vehicle to upper traffic intersection in the green time. In this case, if 6 vehicles pass to the upper traffic intersection, it will make spillback.

Table 1. Waiting queue length depending on passing vehicles in the lower traffic intersection

a: passing cars	length	P.C.U.
1 (small)	4 meter	1.3
2 (small)	4 meter	1.3
3 (small)	4 meter	1.3
4 (small)	3.5 meter	1.25
5 (med)	6 meter	1.5
6 (med)	7 meter	1.6

$$Optimal\ Capacity \geqq Upcap - \sum_{n=1}^{n=6} (Qni)$$

(4+4+4+3.5+6+7)=28.5 METER < 30 METER

upper traffic intersection length: 100 meter

Occupancy of upper traffic intersection length: 70 meter

Capacity of upper traffic intersection length : 30 meter

Expecting number of passing vehicles : 4 vehicles

Effective green light time per each phase can be obtained by Webster method and optimal signal cycle(C_O) can be obtained by the following Eq. (1):

$$Co = \frac{1.5L + 5}{1 - Y} \tag{1}$$

where

Co : OPTIMAL CYCLE TIME

: optimal cycle to minimize traffic delay (second)

Y_i : Q_i / S

QI : ratio of vehicles at the accumulating condition

1 .... accumulation,

0...... passage

S : ratio of vehicles at the congesting condition

L : whole loss of time ===>

END - LAG TIME + START - UP DELAY TIME

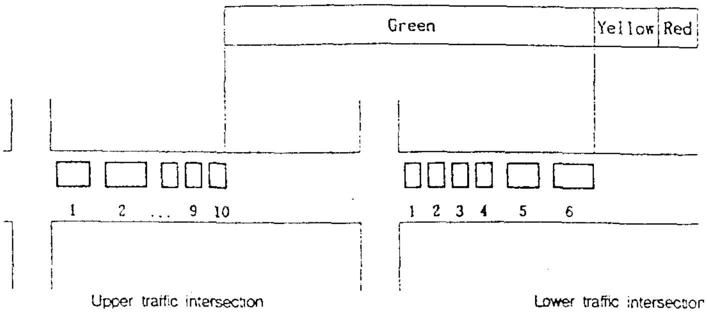

Fig. 1 Green time depending on waiting vehicle queue 1.

Table 2. Wating queue length and P.C.U. depending on passing vehicles in the lower traffic intersection

b passing cars	length	p.c.u.
1 (large)	12 meter	1.7
2 (large)	13 meter	1.8
3 (small)	4 meter	1.3
4 (lmed)	6.5 meter	1.55
5 (med)	6 meter	1.5
6 (med)	7 meter	1.6

⟶ opt. cycle length

(12+13+4+6.5+6+7) = 48.5 meter > 30 meter

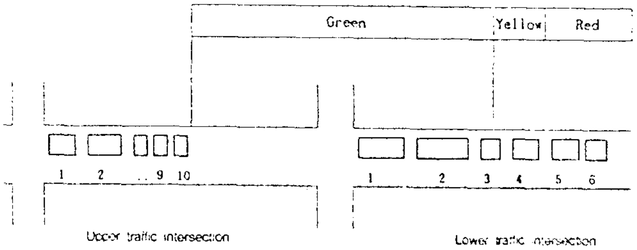

Fig. 2 Green time depending on waiting vehicle queue 2.

upper traffic intersection lengt : 100 meter

Occupancy of upper traffic intersection length: 70 meter

Capacity of upper traffic intersection length: 30 meter

Expecting number of passing vehicles: 3 vehicles

EFFECTIVE GREEN LIGHT TIME of Eqn. (1) can determine 'OPTIMAL TRAFFIC SIGNAL CYCLE' Co by WEBSTER method. It is only applied to limited roads and limited vehicles statistically. It can't be applied to data of movable vehicles. Because the conventional method of OPTIMAL TRAFFIC SIGNAL CYCLE doesn't consider vehicle length depending on consider passenger car unit. Moreover, distance of each blockage, the width of crossroads, the gradient of road (Uphill Road, Downhill Road), It is very difficult to get the optimal traffic cycle using conventional method.

3. Principle of vehicle detecting

All conductors or wires carrying an electrical current produce magnetic flux which links with the current. The effect of this flux is the electrical property called inductance, measured in Henrys(h). The inductance of the wire is called self-inductance. If the flux from current flowing in the wire couples to other wires, the resulting inductance is called mutual inductance. The conventional loop detector installed on a road detects a change of inductance from the presence of a vehicle. The loop sensitivity, SL, of an inductive loop is defined as Eq. (3).

$$SL = 100 * \frac{LNV - Lv}{LNV} = 100 * \frac{\Delta L}{L} \qquad (3)$$

Where

LNv = Inductance with no vehicle

Lv = Inductance with vehicle

Assume the effect of vehicle iron is neglible. Then $\mu r=1$ and the self inductance of the roadway loop is given by Eq. (4)

$$L11 = \frac{\mu o * N * l^2 * A * F1}{L1} \qquad (4)$$

The magnetic field for this coil geometry is given by Eq. (5).

$$H = \frac{N * I}{L} \qquad (5)$$

where

H = Magnetic field, Amphere turns per M

N = Number of Turns

I = Coil current, Amperes

L = Length of coil, M

Because the magnetic flux is uniform inside the coil, the coil flux is given by Eq. (6)

$$\phi = B * A \qquad (6)$$

where

ϕ = Magnetic flux, Webers

A = Cross sectional area of coil m^2

Vehicle detector systems a sense a decrease in inductance of its sensorloop during the passage or presence of a vehicle in the zone of detection of the sensor loop. When a vehicle passes over the loop or is stooped within the loop, It decreases the inductance of the loop.

So, the inductance have 3 different value depending on vehicle speed, vehicle weight, and passing area of loop detector when coming vehicle of lower intersection passes over the loop detector as follows.

Class 1 : 1.13 percent($\Delta L/L$) or 1.12 μh (ΔL) inductance change (Small vehicle)

Class 2: 2.36percent($\Delta L/L$) or 2.13μh (ΔL) inductance change (Medium vehicle)

Class 3: 3.49percent ($\Delta L/L$) or 3.27μh (ΔL) inductance change (Large vehicle)

In Fig. 4, Sensitivity for four classifications of analog vehicle signature have specific values, when they pass the single loop detector(1.8M *1.8 M). But, it is not same passing vehicle speed, passing vehicle weight, and passig area of loop detector when lower traffic intersection of passing vehicles passes over the loop detector. Therefore, it is not easy to classify 4 kinds of passenger car unit. To classify to passenger car unit. To determine passenger car unit using loop detector, weight sensor and pressure sensor are shown in Fig. 5. The passenger car unit is taken from loop detector placed on the road, 25 meter before the traffic light

and 3 fuzzy input membership function and 27 fuzzy logic control rules used to determine optimal traffic cycle.

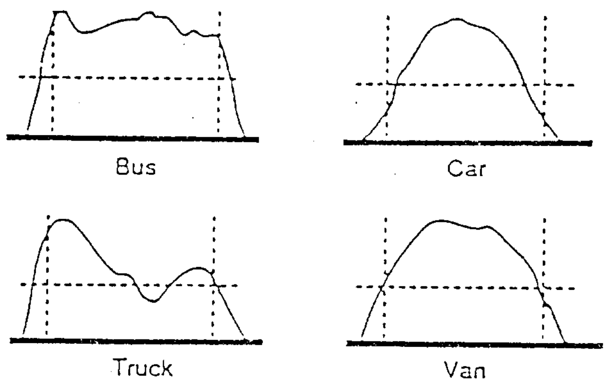

Fig. 3 Passing vehicle analog signature of loop detector.

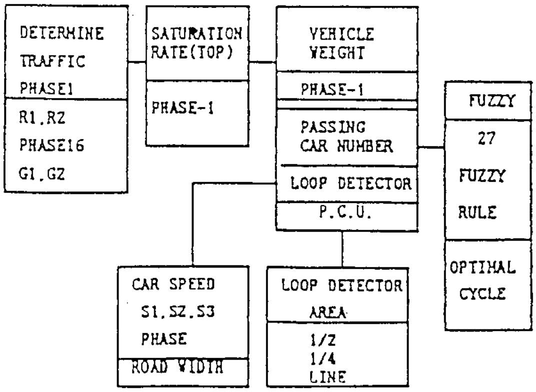

Fig. 4 Block diagram of fuzzy traffic light.

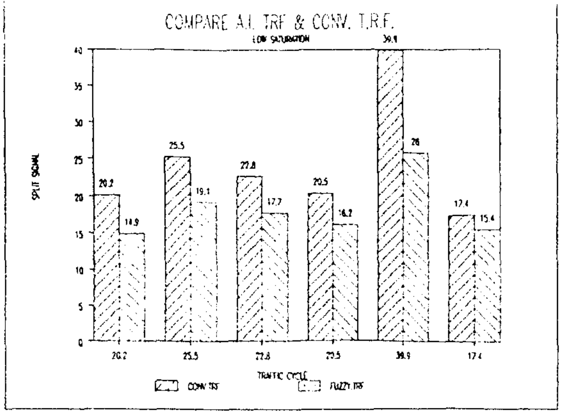

Fig. 5 Compare with wating time for low saturation conventional traffic light & fuzzy traffic light

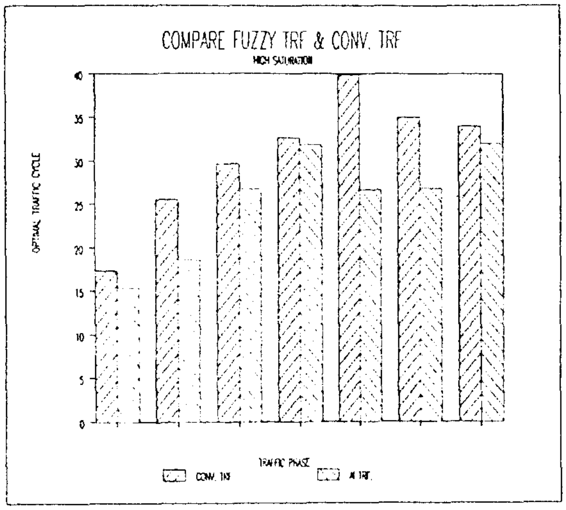

Fig. 6 Compare with wating time for high saturation conventional traffic light & fuzzy traffic light

4. Determination of optimal traffic cycle

In basic traffic-acturated control, the minimum green interval depends on the number of cars that are stored in the loop counter. The number of vehicles is known, the minimum green interval can be calculated. Unfortunately, it is very difficult to determine to pass through the loop detector which vehicle is large or small using conventional traffic control system. Because, the value of inductance of the occupancy time differs when vehicles pass over the center of the lane or 1/2 or 1/4 lane and different passing vehicle spped. So, the best estimated signal cycle can be calculated using the fuzzy logic. In this paper assumed length of traffic intersection is 100M, the length of a small vehicles is 3-4M, the length medium vehicles 5-6M, and the length large vehicles 10-12M.

In order to determine optimal traffic cycle, it need 2 loop detectors, weight sensor, pressure sensor, and speed sensor.

In order to improve P.C.U. , in this paper, we used 3 input fuzzy membership function and 2 output fuzzy membership function. The following is the Fuzzy Logic Control of Traffic Signal Light. On the basis of 'RULE BASE' of 'FUZZY MEMBERSHIP' function under each condition, we use MAX-MIN deduction method and center of gravity method as Defuzzyfication method.

Highsaturation rate (Upper Traffic intersection) ......

TRAFFIC CODE(111)

IF	PA	is	HIGH	ELSE	PA	is	MED	
and	PS	is	MED	and	PS	is	HIGH	
and	WT	is	HIGH	and	WT	is	SMALL	then
	Op	is	HIGH		OP	is	MED	
	Os	is	HIGH		Os	is	HIGH	

PA is Passing area of Loop detector
PS is Passing vehicle speed
WT is Total weight vehicle
OP is Expecting passenger car unit
OS is Expecting passenger car speed

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

5. Conclusion

Results of the fuzzy controller simulations, it compared with fuzzy traffic light considering passenger car unit of vehicle wating time and non fuzzy traffic light of wating time. The fuzzy traffic controller shows reducing wating time at the highsaturated traffic condition. But, in case of low saturated traffic conditions there is a little bit of difference for reducing waiting time with vehicle waiting time of fuzzy traffic light and conventional traffic light. For the fuzzy controller, the average waiting time decreased by 15 percent when compared with the conventional controller. Again, the fuzzy-controller simulation was compared with wating time of T.Q.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 because the conventional signal doesn't have passnger car unit and offset. Finally, Computer simulation confirms that vehicle waiting time is improved by 10-15% even in case of spillback or large vehicle sudden entry.

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