Applied Mechanics and Materials Vols. 321-324 (2013) pp 1836-1841 Online: 2013-06-13
© (2013) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.321-324.1836

Based on road green wave effect of collaborative strategy of signal timing fuzzy control

Yi Zhang[1, a] , Gengsheng Huang [2, b]

[1,2]South China Institute of Software Engineering of GuangZhou University,Guangzhou 510990,China;

[a]zy@sise.com.cn, [b]smart0306@foxmail.com

Key words:intersection; green-wave effect; cooperative policies;signals fuzzy control

Abstract: With growth of Urban Road Traffic Volume and the increase of Road Network Density, correlation between adjacent road intersections is becoming more and more obvious. An intersection traffic signal adjustment tends to affect the health of a number of adjacent intersections road traffic flow. Its congestion may over time gradually spread to within a few blocks and regions all around the intersection. Therefore increasingly high demands of urban traffic signal control make a variety of advanced control technology integration, achieve the purpose to adjust a control parameter, in order to achieve dynamic coordination within the city - wide traffic control, to satisfy traffic demands, and then let the road traffic and the transport demand make a new balance. And This article introduces is the use of the green wave effect collaborative strategies adjacent green extension of fuzzy control in order to solve the problem of coupling between intersections road. This algorithm makes Signal Timing to be more flexible.

Signal Coordinate Control of Road

In this article, we study signal Coordinate Control of adjacent intersections. As showed in Figure 1.We can model it as undirected graph G (V.E), in this figure, V was junctions collection, E was an intersection between roads collection. In the green wave phenomena, many traffic lights collaborate, makes some direction of traffic through multiple junctions in a row by vehicles to maximize the number of vehicles through the intersection, minimize vehicles waiting at the crossing.

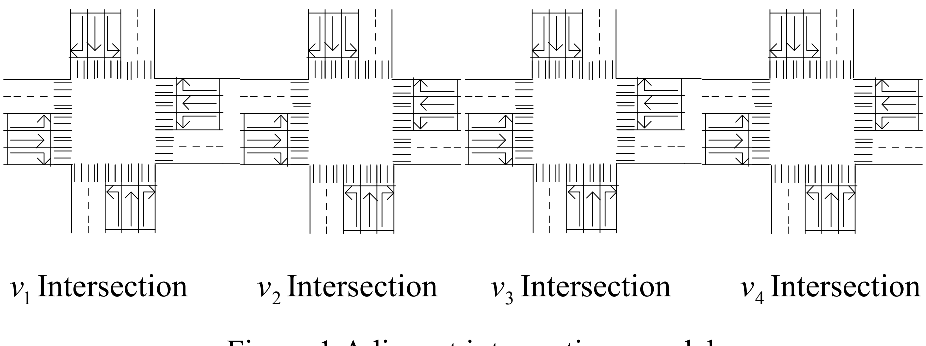

Figure 1 Adjacent intersections model

According to the traffic lights in collaboration with the green wave effects minimized the next time waiting for the vehicle, which is at t moment λ phase the junction to work together to produce the expected utility of the value of the minimum[1].

$\pi^*(\lambda,t) = \mathrm{argmin}_{\mathrm{Jt\_act(G,\lambda,t)}} EU(G,\lambda,t)$, to consider λ as signal phase, according to the change of road right-of-way within a period to divide.

To consider EU(G, λ,t) as t from intersection to intersection and turning intersection utility value of the work was the entire road t+1 moments in each intersection when phase waiting for the sum of the number of vehicles.

$$EU(G,\lambda,t) \;=\; \sum_{v_i \in V} \sum_{vj \in n(V_i)} Tf_i^{\,j}(k,\lambda,t+1) \tag{1}$$

To consider $Tf_i^{\,j}(k,\lambda,t+1)$ as λ phase of the current lane waiting for t+1 moment the number of vehicles ,and to consider *Jt_act*(G, λ,t) as this is a moment t λ phase collection of all the action of traffic lights, that is

Jt _ act(G, λ, t)= $\cup_{V_i \in V} \cup_{Vj \in V} \pounds_i^j(k,\lambda,t)$, and $\pounds_i^j(k,\lambda,t)$ ∈{green , red} show the light to change to green and red.

According to the person who name Xu yang and the other person put The Predictive Model to us ,we can calculate the leave and arrival of the number of intersection vehicle ,the next moment, λ phase the number of vehicles in the driveway) equal to the number of vehicles waiting to be minus the left of the number of vehicles and adds the number of vehicles to arrive that is

$$Tf_i^{\,j}(k,\lambda,t+1) = Tf_i^{\,j}(k,\lambda,t) + \mathrm{Tc}_i^j(\mathrm{k},\lambda,\mathrm{t}) - \mathrm{Td}_i^j(\mathrm{k},\lambda,\mathrm{t}) \tag{2}$$

To consider $\mathrm{Td}_i^j(\mathrm{k},\lambda,\mathrm{t})$ as λ phase of the current lane leaving for t+1 moment the number of vehicles: We assume that every lane in a green light cycle through the maximum number of vehicles to δ, if $\pounds_i^j(k,\lambda,t)$ = green, $\mathrm{Td}_i^j(\mathrm{k},\lambda,\mathrm{t})$ = $Tf_i^{\,j}(k,\lambda,t)$<=δ; but if $\pounds_i^j(k,\lambda,t)$=red, $\mathrm{Td}_i^j(\mathrm{k},\lambda,\mathrm{t}) = 0$.

To consider $\mathrm{Tc}_i^j(\mathrm{k},\lambda,\mathrm{t})$ as λ phase of the current lane leaving for t moment the number of vehicles equal to the previous green light cycle selects the number of vehicles entering the lane. Observation of statistical and historical data we can get the λ phase vehicle selection probabilities lane is $\beta_{\,i,j,k}$

$$\mathrm{Tc}_i^j(\mathrm{k},\lambda,\mathrm{t}) = \beta_{\,i,j,k} \times \sum_{V_l \in n(V_j) \wedge V_l \neq V_i} Td_j^{\,l}(i,\lambda,\mathrm{t}) \tag{3}$$

Signal cycle generally should not exceed 200s because cycle too long causing drivers impatient, running the red light or forced line.

Calculate adjacent junctions V_i signal with fuzzy control thought

(1) set the time of minimum green light to each phase $G_{\min}$ =15s;

(2) when control start, the moment of the λ phase of green light to the end and the yellow light begins to flash, according to the strategy of $\pi^*(\lambda,t)$,to obtain the number of the λ +1 phase waiting vehicles and the number of the λ +2 phase waiting vehicles;

(3) calculate the difference between the number of the λ+2 phase waiting vehicles and the number of the λ+1 phase waiting vehicles and credited as X, as well as the difference between the number of vehicles pull into the adjacent intersection and the number of vehicles put out of it and credited as Y= $\mathrm{Tc}_i^j(\mathrm{k},\lambda,\mathrm{t}) - \mathrm{Td}_i^j(\mathrm{k},\lambda,\mathrm{t})$,get fuzzy control of the two inputs;

(4) look-up the procedures to get the green light delay GE, resulting in the time of phase green light $G_{time} = G_{\min}$ +GE;

(5) After the λ phase red light brightens, the λ +1 phase yellow light brightens and green light brightens 3s later, control the green time according to the Gtime got from the table in the last step;

(6) When the time of the λ +1 phase green light ends and the yellow light brightens, begin to receiving the next phase data, thereby the signal's intelligent controls accomplished.

2.1 Input parameters X, Y of Fuzzification

①According to the actual situation, determine the actual variation range(basic domain) of X and Y, [-30, -30] and [-60,60]respectively. Discretization of the basic domain in accordance with the general canonical form: {-n, -(n-1), ...,-1,0,1, ..., (n-1), and n}. When use the fuzzy control, generally do not target high control accuracy, therefore on the discrete point s in the domain is not too large. According to the requirement of control accuracy to be achieved, select n is 7,that is the quantization on domains are: {-7, -6, -5, -4, -3, -2, -1,0,1,2,3, 4,5,6,7}. The relationship between discrete values and the input exact value can be obtained according to the quantization factor:

X discrete value=INT the (K_x ×actual input to the precise amount+0.5) K_x =7/30 (quantization factor); Y discrete value= INT (K_y ×actual input to the exactamount+0.5) K_y =7/60 (quantization factor)

②fuzzy control's linguistic variable sand variable selection, its principle should not only consider the flexibility often control rules, but also take into account the simple, we selected: NB (negative big), NM (negative medium), NS(negative small) ZO (zero), PS (positive small), PM(positive median), PB (positive big).The linguistic variables of domain fuzzy subset described by the membership function, the membership function u can determine by summarize the expertise or statistical methods. The membership function of X shown in Table 1, the membership function of Y is the same as X.

Table 1 The membership function of X

Quantify domain / u / X	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7
NB	1	0.8	0.4	0.1											
NM		0.2	0.7	1	0.7	0.2									
NS				0.1	0.4	0.8	1	0.4							
ZO							0.5	1	0.5						
PS								0.4	1	0.8	0.4	0.1			
PM										0.2	0.7	1	0.7	0.2	
PB												0.1	0.4	0.8	1

2.2 output(green light delay) GE fuzzification

①its basic domain in[0,50], consider the green light delay only has the positive, the quantization domain is: {0,1,2,3,4,5,6,7,8,9,10}. Follow the scale factor to get their relationship between discrete valuesand the exact amount of the actual output:

The actual output of the exact amount= K_u × discrete values

$$K_u = 50/10 \text{ (scale factor)} \tag{4}$$

②fuzzy control's language variables and variables election: zero(G_0),very short(G_1),short(G_2),medium(G_3),longer(G_4),long(G_5).Membershipfunctio u shown in Table 2

Table 2 Membershipfunctio u

Quantify domain u / GE	0	1	2	3	4	5	6	7	8	9	10
zero	1.0	0.5									
very short		0.5	1.0	0.5							
short				0.5	1.0	0.5					
medium						0.5	1.0	0.5			
longer								0.5	1.0	0.5	
long										0.5	1.0

2.3 Fuzzy control rule table creation

The establishment of fuzzy control rule is very important, whether the rules can correctly reflect the expert experience and knowledge, whether it can effectively control the object, is directly related to the performance of the controller. Control experience-based summary 49 control rules are as follows Table 3:

Table 3 Fuzzy control rules

GE X / Y	NB	*NM*	NS	ZO	PS	PM	PB
NB	zero	*zero*	zero	zero	zero	zero	zero
NM	zero	*zero*	zero	zero	zero	zero	Very short
NS	zero	*zero*	zero	zero	zero	Very short	Short
ZO	zero	*zero*	zero	zero	Very short	Short	Medium
PS	zero	*zero*	zero	Very short	Short	Medium	Longer
PM	zero	*zero*	Very short	Short	Medium	Longer	Long
PB	zero	*Very short*	Short	Medium	Longer	Long	Long

2.4 Fuzzy inference algorithm defuzzification

In general, the results obtained from the fuzzy rules are still fuzzy quantity, but also through fuzzy reasoning algorithm for accurate reduction amount in order to output. According to the fuzzy synthesis reasoning rules, the fuzzy control rules are a synthesis of the output of a fuzzy set:

For example: if X_i and Y_j then GE_m

(i, j in [NM, NS ,NB, ZO, PS, PM, PB]; m in [zero, very short, short, medium, longer, long]

The fuzzy relation

$$\tilde{R} = [\, X_i \times Y_j \,]^{T_1} \times GE_m \tag{5}$$

Wherein T_1 represents the relationship between a matrix operation, the purpose is to a 15 × 15-dimensional matrix transpose into a 225 x 1-dimensional column vector, and finally get a 225 × 11-dimensional matrix. Each fuzzy relationship matrix is 225 × 11 dimensions, a total of 49.

Assume that the input variable X is 3.Membership function maximum value corresponding to the interval PM, let a= (0,0,0,0,0,0,0,0,0,0.2,0.7,1,0.7,0.2,0); input variable Y is -2, membership function maximum value corresponding to the interval of NS b= (0,0,0,0.1,0.4,0.8,1,0.4,0,0,0,0,0,0,0).According to the fuzzy synthetic arithmetic calculation: According to the fuzzy synthetic arithmetic calculation:

$$\mathrm{C}=(\mathrm{a}\times\mathrm{b}\,)^{T_2} \circ \tilde{R} \tag{6}$$

Wherein T_2 represents a matrix operation, the purpose is the matrix transpose of a 15 × 15 dimensional row vector dimension into a 1 × 225, for the fuzzy rules: if X = PM and Y = NS then $GE = G_1$ Fuzzy relationship matrix.

Eventually get to a 1 × 11 dimensional vector. Fuzzy weighted average method is more commonly used, has good stability, its output is continuous but not jumping.

Assuming the output c is: $(c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8, c_9, c_{10}, c_{11})$, each of which an c_i value [0,1]. It is the weighted average of the green light time delay:

$$\mathrm{GE}=\sum(i \times C_i) \,/\, \sum C_i \qquad i \text{ in [1-11]} \tag{7}$$

The final phase of the effective green time: $G_{time} = G_{\min}$ +GE. After conversion, the green light in the other direction, and repeat the process.

Conclusion

Based on the green wave effect, the use of fuzzy control methods, such as artificial neural networks technology traffic light control system for global optimization scheduling system. Local fuzzy control strategy must follow the principles of the global optimum. We can use the Markov decision process to select the optimal control behavior. The fuzzy control strategy is a composite strategy. It can be adjusted under the control of the control center. Entry a lot of fuzzy Data, to train the neural network in order to achieve global optimization scheduling. Although there are still many problems in the global regulation and local control with the use of fuzzy pending to resolve, but as the studies continue, the method will be a good way to solve the problem of Small and Medium Cities in China urban traffic control.

Take control of a variety of advanced technologies integrated with each other to achieve the purpose of intersection adjusts a control parameter, in order to achieve dynamic coordination of traffic throughout the city-wide control, meet the need of traffic demands, let traffic roads and traffic needs reach new dynamic balance, build a scientific, system control system for urban traffic.

References

[1] Xu Yang+.“Agent-Based Decentralized Cooperative Traffic Control Toward Green-Waved Effects” [J], Journal of Software,2012,11(2939).

[2] Li Ling Xi. “ Control Signal Coordination of Two Adjacent Traffic Intersections” [J], ACTA AUTOMATICA SINICA, 2003,29(6).

[3] Gao Jun Xia.“ Probe into Fuzzy Control and Simulation in Multi-phase Isolated Intersection” [J], Computer and Communications , 2004,2(22).

[4] Li Jing. “ The fuzzy algorithm control for Single road intersection traffic light and its simulation” [J], Microcomputer Information ,2006,3-1：33-35.

[5] Cheng Wei.“ A Study on Traffic Control of Signalized Intersection Based on Fuzzy Logic” [J], Journal of Kunming University of Science and Technology , 2004,29(3).

Mechatronics and Industrial Informatics
10.4028/www.scientific.net/AMM.321-324

Based on Road Green Wave Effect of Collaborative Strategy of Signal Timing Fuzzy Control
10.4028/www.scientific.net/AMM.321-324.1836