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Research on Signal Timing System Optimization under the Background of Intelligent Transportation

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Abstract

Traffic signals are an important part of traffic management, of which the intelligent traffic signal timing system is an indispensable part of the intelligent transportation system. In order to improve the congestion of urban road intersections and improve their traffic capacity, this paper is based on the principle of automatic control of signal timing, based on the 15min flow rate, the traffic volume prediction is carried out by the gray prediction method (1, 1), and the prediction results are used to guide the optimization of the signal light timing at the road intersection, and the genetic algorithm is used to optimize the traffic lights at the trunk intersection based on the principle of continuous coordinated control, solve the optimal timing scheme, and implement it in MATLAB language. Later, taking an intersection in Lhasa as an example, the traffic simulation evaluation of the information and distribution system was carried out through the VISSIM5.3-03 simulation platform, and the simulation results showed that the algorithm had feasibility and certain advantages.

Keywords

Signal timing, Genetic algorithms, Grey forecasting, Traffic simulation

1. Introduction

To some extent, urban traffic congestion has become a bottleneck restricting the sustainable development of the urban economy and society. The intelligent signal control system can effectively reduce the idle time of cars waiting, optimize the allocation of traffic resources, to a certain extent, alleviate traffic accidents and environmental pollution caused by traffic congestion, and promote the construction of smart cities.

Based onwebster's green-letter ratio optimization model, Yuan et al. restricted the timing of the signal timing to the rest of the signal lights associated with it, to achieve an optimization mode of one congestion and multiple joint regulations [1]. Considering the time value and exhaust pollution loss, Wan and others used a two-layer planning model for signal lamp matching, which resulted in a reduction in both economic losses and vehicle exhaust emissions by about 30% [2]. Li et al. introduced the evolutionary game theory and selection mechanism, aiming at the minimum average delay time of vehicles at intersections, and improved the control effect of intersections [3].

In this paper, traffic volume is predicted based on the 15-min flow rate using the grey prediction method (1, 1), and the prediction results are used to guide the optimization of signal timings at road junctions. The traffic signals at arterial junctions are optimized in conjunction with genetic algorithms based on the principle of sequential coordinated control, and the optimal timing scheme is solved and implemented in MATLAB.

2. Traffic signal timing optimization

The signal timing system optimization in the context of intelligent transport in this study is based on inductive control, which uses an intelligent control machine to adjust the traffic signal timing at any time to divert vehicles based on real-time sensed traffic flow information at the intersection [4]. The traffic signal timing optimization model in this paper, based on a node-intersection signal timing optimizationsystem [5], is shown below.

2.1 Short-term traffic flow forecast based on grey forecast

2.1.1 Grey Predictive Model Modeling

Set the traffic flow data as:

$$x^{(0)} = \left(x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n)\right)$$

Level ratio$\sigma^{(0)}(k)$ is: $\sigma^{(0)}(k) = \frac{x^{(0)}(k-1)}{x^{(0)}(k)}$

When $\sigma^{(0)}(k) \in (e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}})$,Sequence $x^{(0)}$ can be modeled as $GM(1,1)$, and the level is considered to meet the requirements; When $n = 4,5,6,\dots$, the overridable$(e^{-\frac{2}{n+1}}, e^{\frac{2}{n+1}})x^{(0)}$are:

$$n = 4, \sigma^{(0)}(k) \in [0.670320046, 1.491824698]$$
$$n = 5, \sigma^{(0)}(k) \in [0.716531310, 1.395612425]$$
$$n = 6, \sigma^{(0)}(k) \in [0.751477292, 1.330712198]$$
$$\dots\dots$$

Transform the raw data so that the processed sequence level ratio can fall within the tolerable coverage interval. Sequences with a ratio of unqualified grades can be processed to ensure $GM(1,1)$ modeling. $GM(1,1)$modeling of traffic flow data using the additive method. The specific process is:

(1) Make a one-time accumulation of the original data

Let the original gray traffic flow data be $x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)$, and note as:

$$x^{(0)} = (x^{(0)}(1), x^{(0)}(2), \dots, x^{(0)}(n))$$

To add it up once, you get:

$$\mathrm{x}^{(1)} = (\mathrm{x}^{(1)}(1), \mathrm{x}^{(1)}(2), \cdots, \mathrm{x}^{(1)}(\mathrm{n}), \mathrm{k} = 1,2, \cdots, \mathrm{n})$$

Thereinto:$\mathrm{x}^{(1)}(k) = \sum_{i=1}^{k}(x^{(0)}(i))$.

(2) Establish a $GM(1,1)$ model

$$\frac{d\mathrm{x}^{(1)}}{dt} + a\mathrm{x}^{(1)} = u$$

where a,u is constant and is obtained by fitting the least squares method:

$$\binom{a}{u} = (B^T B)^{-1} B^T Y_n$$

Thereinto:

$$B = \begin{bmatrix} -\frac{1}{2}\ (x^{(1)}(1) + x^{(1)}(2)) & 1 \\ -\frac{1}{2}\ (x^{(1)}(2) + x^{(1)}(3)) & 1 \\ \vdots & \vdots \\ -\frac{1}{2}\ (x^{(1)}(n-1) + x^{(1)}(n)) & 1 \end{bmatrix}$$

$Y_n = \left(x^{(0)}(2), x^{(0)}(3), \cdots, x^{(0)}(n)\right)$,The time response function is:

$$\hat{x}^{(1)}(k+1) = (x^{(0)}(1) - \frac{u}{a})e^{-ak} + \frac{u}{a}$$

Restored predictions for the original sequence:

$$\hat{x}^{(0)}(k) = (x^{(1)}(k) - x^{(1)}(k-1))$$

2.1.2 Model Testing

In this paper, the accuracy of the $GM(1,1)$ model is tested by means of residual test, posterior difference test, and fractional deviation test.

(1) Residual test. First define the relative error $\varepsilon(k)$, the mean relative error $\varepsilon(avg)$, and the precision p^0:

$$\varepsilon(k)=\frac{q(k)}{x^{(0)}(k)}\times 100\%=\frac{x^{(0)}(k)-\hat{x}^{(0)}(k)}{x^{(0)}(k)}\times 100\%$$

$$\varepsilon(avg)=\frac{1}{n-1}\sum_{k=2}^{n}|\varepsilon(k)|$$

$$p^0=\left(1-\varepsilon(avg)\right)\times 100\%$$

For $\varepsilon(k)$, the general requirement is $\varepsilon(k)<20\%$, preferably $\varepsilon(k)<10\%$; for $p^0>80\%$, preferably $p^0>90\%$.

(2) Posterior error test. The mean and variance of $x^{(0)}$ are:

$$\bar{x}=\frac{1}{n'}\sum_{k=1}^{n}x^{(0)}(k)$$

$$S_1^2=\frac{1}{n}\sum_{k=1}^{n}(x^{(0)}(k)-\bar{x})^2$$

The mean and variance of $q^{(0)}$ are:

$$\bar{q}=\frac{1}{n'}\sum_{k=1,}^{n'}(q(k),n'<n;)$$

$$S_2^2=\frac{1}{n'}\sum_{k=1}^{n}(q(k)-\bar{q})^2$$

The posterior difference ratio C and the small error frequency P are:

$$C=\frac{S^2}{S^1}$$

$$P=P\{|q(k)-\bar{q}|<0.6745S_1\}$$

(3) Grade ratio deviation test. For a given sequence $x^{(0)}$ and model sequence $\hat{x}^{(0)}$, the sequence stage ratio$\sigma^{(0)}(k)$ and the model level ratio $\hat{\sigma}^{(0)}(k)$ are:

$$\sigma^{(0)}(k)=\frac{x^{(0)}(k-1)}{x^{(0)}(k)}$$

$$\hat{\sigma}^{(0)}(k)=\frac{\hat{x}^{(0)}(k-1)}{\hat{x}^{(0)}(k)}=\frac{1+0.5a}{1-0.5a}$$

The step ratio deviation is:

$$\rho(k)=\frac{\hat{\sigma}^{(0)}(k)-\hat{\sigma}^{(0)}(k-1)}{\hat{\sigma}^{(0)}(k)}\times 100\%$$

If ε(k) is a specified real number, the $GM(1,1)$ model called $x^{(0)}$ has a ε exponential coincidence rate when $\rho(k)<\varepsilon$.

2.2 Node intersection signal timing optimization

This article selects the traditional node signal timing calculation method.

(1) Signal period: $C_0=\frac{1.5L+5}{1-Y}$.

$C_0$is practical signal period(s); L is the total signal loss time(s); Y is the sum of the traffic ratios.

(2) Signal total loss time: $L=\sum_k(L_s+I-A_k)$".

$L$is the signal total loss time(s); L_s is the starting loss time (usually 3s); A is the duration of the yellow light (generally 3s); I is the green light interval time(s); k is the number of green light intervals in a cycle.

(3) Green light interval time: $I=A+AR$.

$I$is the green light interval time(s); A is the yellow light duration(s); AR is the full red duration(s).

(4) Yellow light time: $A=t_r=\frac{v_0}{2a}$

$t_r$is the driver's reaction time (generally take 1s); v_0 is the travel time(s) when the vehicle is green; a is a brake deceleration (m/s^2). In the absence of actual data, the yellow light time is generally taken for 3s.

(5) Full red time: $AR = \frac{\Delta L_{max} + L_c}{v_0}$

L_c is the body length (m); ΔL_{max} x is the maximum value (m) of the distance between the first car in each lane of the current phase to the point of conflict and the distance between the first car of each lane in the next phase to the point of conflict. In the case of data lack, the full red time is generally taken 0 to 3s.

(6) The sum of the flow ratio:

$$Y = \sum_{j=1}^{j} max(y_{j,} y_j{}', \cdots) = \sum_{j=1}^{j} [(\frac{q_d}{S_d})_j, \frac{q_d}{S_d})_j{}', \ldots (Y \leq 0.9)]$$

Y is the sum of each maximum flow ratio of each signal phase that makes up the cycle; j is the number of signal phases; y_j、$y_j{}'$ is the flow ratio of the j phase; q_d is the amount of traffic (pcu/h); The S_d is the saturated flow rate (pcu/h). When $Y>0.9$, the signal phase needs to be redesigned and calculated.

(7) Effective green light time: $G_e = C - L$

(8) Effective green light time for each phase: $g_{ej} = G_e \frac{\max(y_j, y_j{}', \ldots)}{Y}$

(9) The green letter ratio of each phase: $\lambda = \frac{g_{ej}}{C_0}$

(10) Green light time display for each phase: $g_j = g_{ej} - A_j + l_j$

l is the j phase start loss time(s).

(11) Minimum green light time: $g_{min} = 7 + \frac{L_p}{v_p} - I$

L_p is the length of the pedestrian crossing (m); v_p is the pedestrian crossing speed (take $1m/s$); I is the number of green light intervals.

2.3 Trunk line intersection signal timing optimization

The mathematical model of coordinated optimization of trunk line intersection communication is based on the goal of the minimum delay time of the total vehicle of the green wave system. Modeling the following:

$$min\, t = \bar{t}_{OD} + d = \bar{t}_{OD} + \sum_{k=1}^{n} d_{k1}$$

$$s.t. \begin{cases} d_{ki} \leq d_{ki}, \sum_{i=1}^{2} g_{ei} = c - L \\ geiij_{max}{}_{,min} \end{cases}$$

3. Examples and traffic simulation evaluations

3.1 Location Selection

The test site was selected at an intersection in the city of Lhasa, as shown in Figure 1.

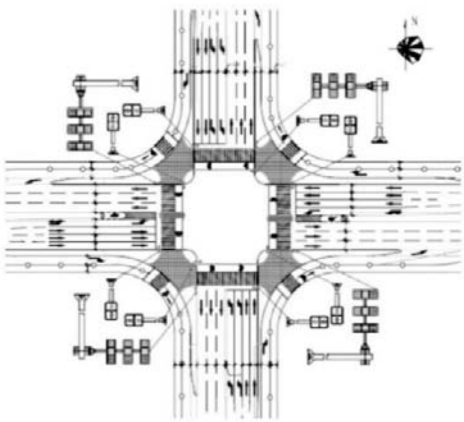

Figure 1. An intersection in Lhasa.

Since traffic congestion is easy to occur at this intersection in Lhasa in the morning and evening rush hours, the traffic signal is set in two phases, as shown in Figure 1, with a signal period of 81s. Among them, the first phase is straight left and right traffic, and the light color distribution is: green light 50 s, yellow light 3s, red light 28s; The second phase is the south trunk canal street straight left and right traffic, the light color distribution is: green light 21s, yellow light 3s, red light 57s.

3.2 Traffic Flow Forecasting

Table 1. Traffic flow forecast

Lane direction	Go straight	Turn Left	Turn right	Traffic volume/throughput capacity of each inlet	Total traffic/passage capacity of the inlet road
North	743	36	87	436/1043	1557/2564
South	597	72	59	703/1005	
West	48	63	100	167/210	
East	69	167	58	251/306	

Under the condition of 95% confidence, the sample capacity was 313 vehicles, the total delay was 4695 (units· s), the average delay of each vehicle was 26.2s, and the percentage of stoppage was 50.56%; Under the condition of 95% confidence, the sample capacity was 304 vehicles, the total delay was 3825 (units· s), the average delay of each vehicle was 21.4s, and the percentage of parking was 58.88%.

3.3 Trust distribution optimization

The calculation method of the timing algorithm of the node signal intersection is adopted. Among them, when calculating the saturation flow of each lane, attention should be paid to distinguishing the conversion coefficients of different functional guiding lanes and calculating the traffic capacity of different guiding lanes. Traffic signals take a two-phase setting with a signal period of 70s. Among them, the first phase is the garden road straight left and right, and the light color distribution is: green light 40s, yellow light 4s, red light 26s; The second phase is the south trunk canal street straight left and right traffic, the light color distribution is: green light 15s, yellow light 3s, red light 52s. After optimization, the traffic simulation evaluation of the communication and distribution system is carried out by the VISSIM5.3-03 simulation platform, and the simulation results show that the algorithm has feasibility and certain advantages.

4. Conclusion

Traffic signals are an important part of traffic management, and the intelligent traffic signal timing system is an indispensable part of the intelligent traffic system. For the traffic signal timing problem, the idea of gray prediction model GM(1,1) and genetic algorithm is used to write the trust optimization algorithm and implement it in MATLAB language. The algorithm calculates the optimal timing with a 15min flow rate at the inlet and realizes the coordination of the timing of the trunk intersection through the genetic algorithm. Use the VISSIM5.3-03 simulation platform to simulate the environment and prove the feasibility and superiority of the algorithm.

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