

Research on Timing Optimization of Regional Traffic Signals Based on Improved Genetic Algorithm

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Abstract: The problem of urban traffic congestion is becoming more and more serious. In recent years, the coordinated control of regional traffic signals has become a hot topic in the study of intelligent traffic control. For a long time, genetic algorithm is an important timing optimization method of regional traffic signals. The paper points out the advantages and disadvantages of genetic algorithm in the timing optimization scheme of regional traffic signal, explores the optimization scheme based on the improved genetic algorithm in regional traffic signal timing and draws the corresponding flow chart. In this paper, a four-intersection area is simulated to optimize the timing of regional traffic signals by the means of genetic algorithm and improved genetic algorithm. Practice has proved that in the process of optimizing regional traffic signal timing, the improved genetic algorithm has a better performance in terms of convergence speed compared to genetic algorithm.

1. Introduction

Traffic signal control realizes effective and flexible management of traffic flow by controlling the right of traffic at intersections. Practice has proved that the implementation and optimization of signal control schemes play a positive role in improving the efficiency of urban road traffic system. The effect is made. With the increase of traffic demand at the intersection, especially when the traffic demand exceeds the intersection capacity, that is, when the intersection is over saturated traffic conditions, the vehicle queues generated by the intersection will quickly add, even overflow to the upstream intersection and spread to the surrounding sections, thereby reducing the traffic capacity of the traffic network. In this case, the traffic management department needs to take effective means of optimizing the regional traffic signal timing parameters to evacuate the queue, alleviate congestion or prevent the formation of traffic congestion ahead of time. However, the complexity of traffic operation under the condition of supersaturation increases the difficulty of signal timing optimization.

At present, several regional traffic signal control systems at home and abroad are slightly weak when dealing with supersaturated conditions. There are also some defects and problems in the optimization method of traffic signal timing parameters in various regions, which are shown in the next few aspects. First, the partial traffic signal control system lacks the effective means of traffic signal timing parameters optimization under the condition of supersaturation, and it cannot effectively realize the traffic signal timing optimization under the condition of supersaturation. Second, the optimization of signal timing parameters under the condition of supersaturated traffic usually takes the fixed optimal target as the traffic signal control strategy, and then the linear or nonlinear mathematical optimization model is constructed to optimize the solution of the timing parameters. The complex mathematical model and its solution process increase the calculation of the signal control system. It is difficult to guarantee the real-time performance of the system. When the model has large accumulative error, the stability and



reliability of signal timing optimization system is difficult to be guaranteed. Third, there is a certain degree of conflict and contradiction between the global optimization and the local optimum in the traffic signal control timing optimization method at the regional level.

Although traditional fixed cycle signal control is easy to implement, it does not consider the choice of travel path for travel users. Aiming at the travel demand of urban area network, this paper optimizes the signal timing based on genetic algorithm to minimize the total delay of trip network. When solving the time allocation problem of regional network, a bilevel programming model is built to optimize the signal timing scheme. The improved genetic algorithm is a heuristic algorithm, so it has obvious advantages in solving the bilevel programming problem with multivariable global optimization.

2. Theory of traffic signal control

2.1 Control models

The common control methods of the traffic signal control system include the fixed cycle traffic signal control mode, the semi induced traffic signal control mode and the full induction traffic signal control mode. The fixed cycle traffic signal control method takes the traffic flow information of the historical network as the data support, and analyses and determines the signal cycle of the final traffic signal timing scheme, the long and phase time sequence of the traffic lights. Once the scheme is implemented, the cycle time, the green light duration and the phase sequence of the traffic signal system remain unchanged for a certain day. It is necessary to formulate a fixed cycle traffic signal control scheme suitable for a intersection in the road network. Through the observation of the traffic flow information at the intersection by season and time periods, the traffic dynamics in each time will be mastered, and the mathematical model is analysed and established. Finally, the required scheme is obtained. As the cross section of the road network intersected by the main line and the sub trunk line, the length of the green light set in the road traffic signal system will be a part of a waste, and the semi inductive traffic signal control method effectively improves the efficient utilization of the green light. Its operation principle is: for intersection area of intersection road network, if the sub trunk line does not pass through the traffic flow in a period, the traffic signal of the main trunk line always shows green, and when the inductor senses that the secondary trunk line has traffic flow into the entrance of the intersection, the traffic signal passes through a short signal and gives its passage. The road signal of the trunk line is changed from green light to red light, and the road signal of the sub trunk line is changed from red light to green light until the traffic flow of the induced sub trunk line is completely passed through the road intersection. It should be noted that the green light time given to the secondary trunk cannot exceed the maximum value set by the communication number control system at this time. The green signal ratio of the full induction traffic signal control method is determined by the traffic flow induced by the inductor in a certain range. The green light time is often changed randomly, but the range is usually changed between the predetermined minimum and the maximum. The priority of the phase is also set in advance. Yes. The full induction traffic signal control method can adjust the green light duration and the traffic signal cycle length according to the real-time traffic flow information at the road intersection.

2.2 Common parameters

Phase, cycle and phase difference are the main parameters of traffic control system. Optimizing the basic parameters of traffic signals is the main way to study the coordinated control of regional traffic signals. In traffic control system, phase is the most basic control parameter. For a crossroad, the state time of the light group that makes traffic flow without conflict in all directions in the intersection is called phase time, and the traffic flow that obtains the right of traffic within the phase time constitutes a phase. In addition to the basic principle of "no conflict", the phase setting must be set according to the actual situation. The factors to be considered are the characteristics of the intersection, the size of the vehicle, the average speed and the time of the pedestrian crossing the street. In traffic control, the sum of the time from the starting phase to the end phase of the timing scheme is a period. Besides the phase time, the transition time of the phase switching is also included, mainly the green light flicker time and the

yellow light time. The size of the cycle must be suitable, the cycle is too small, so the proportion of the transition time is too large, which will seriously reduce the efficiency of traffic control, the cycle is too large, so the time of each phase is relatively large, when the traffic flow is in a certain phase, the next phase of the cross flow will have to wait a long time. In the study of regional traffic signal coordination control, phase difference parameters must be used to link isolated intersections in the region. Phase difference can reduce vehicle stopping times and waiting time. Assuming that two intersections A and B adopt the same cycle, the time for selecting a phase to start the phase P at the reference phase P. a intersection is $time_1$, and the B intersection starts to execute the phase P at $time_2$, then the phase difference between A and B is $ph = |time_1 - time_2|$.

2.3 Evaluation indexes

Various indicators in traffic control are used to evaluate the performance of a traffic control system. The main indicators include the number of stops, queuing length and traffic volume. The number of parking is the number of stops during the car because of the red light, the number of parking will not only affect the traffic, but also due to the increase in the exhaust gas of the vehicle in the process of parking and the process of starting, the sound of the horn will increase, so it will also affect the pollution range of the surrounding environment. When the number of lanes, traffic volume, speed and other factors are similar, the smaller the number of parking, the better the performance of the traffic control system. Parking is divided into full parking and incomplete parking. The parking delay is not the same in these two cases. Complete parking means that the speed of the vehicle is reduced to zero restart in the process of parking, and the incomplete parking refers to the speed that the speed of the vehicle is not reduced to zero during the parking process. The reason for the distinction between the two cases is to build the vehicle. The relationship between the number of standing parking and the delay of the vehicle. Queuing length refers to the length of the tail of the vehicle queue to the stop line due to the stopping of the red light. In actual traffic, the long queue length of two adjacent intersection will result in the "Domino" effect, which is caused by traffic jam on a section of a section, causing the traffic situation of a trunk line or area. Traffic volume can be divided into traffic flow volume, intersection traffic volume and regional traffic volume. The traffic flow volume is the basis, which refers to the total number of vehicles passing through a traffic flow at the intersection under the control of the internal traffic control system for a period. The traffic volume of each intersection can be accumulated by the traffic volume of each traffic flow, and then the total traffic volume in the time zone can be calculated. The capacity of an intersection refers to the maximum traffic volume of the intersection within a unit time.

3. Timing optimization of regional traffic signals based on improved genetic algorithm

3.1 Genetic algorithm

Genetic algorithm is a self-organizing and adaptive AI technology. In the algorithm, the initial solution is called initial population, and usually the population is generated randomly according to certain constraints. The population can be further divided into independent individuals, also known as chromosomes, which is one solution to the problem, and all individuals constitute an understanding space. Individuals are usually represented by code strings consisting of binary character sets $\{0, 1\}$, which are used to describe various parameters in practical problems. In the iterative process of algorithm, the evolution of each generation is called heredity. The genetic process consists of three operation operators, namely, selection operator, crossover operator and mutation operator. In addition, the individual's good and bad in the genetic process is evaluated by the fitness, and the fitness is calculated by the adaptive function to everyone in the population. The greater the fitness of the individual, the more the solution it represents is closer to the optimal solution, the greater the probability of being selected to the next generation. The probability of elimination is greater, which is consistent with the idea of "survival of the fittest" in evolution theory. The role of hybridization and mutation in biological evolution mechanisms is to increase individual diversity, which may destroy good individuals or improve poor individuals. This part is called crossover and mutation in the algorithm, which is carried

out after selecting the population. According to the corresponding crossover and mutation probability, these two operations are applied to the selected individual to produce new individuals, through the selection, cross and mutation operation of each generation, and under the constraints of the maximum genetic algebra and genetic terminating conditions, the algorithm will converge to the optimal solution or close to the optimal solution.

3.2 Applications of genetic algorithm in timing optimization of reginal traffic signals

Fitness function is the guiding rule of evolutionary mechanism of genetic algorithm. The more complex the function is, the slower the algorithm searches for the optimal solution in coding space. Fitness is used to evaluate the relative pros and cons of everyone in the population, and it plays a decisive role in the genetic algorithm as a standard for preserving excellent individuals and eliminating inferior individuals. The objective function with minimum value is transformed into fitness function.

$$F = \begin{cases} C - f(x) & f(x) < C \\ f(x) & f(x) \geq C \end{cases}$$

Coding is the way of individual recording, and many binary encoding methods are used in the research and application of genetic algorithms. However, in recent years, there have been some non-binary coding methods, such as real number coding, for the problem of different fields, which are used in constrained optimization problems and integer coding, which is used in combinatorial optimization problems. In addition, it can also be encoded with floating point numbers. Because coding is related to the evolution level of the algorithm, it is necessary to select the appropriate coding form for different problems. Selection is the first step in the algorithm to reflect the genetic mechanism. The function is to choose individuals with high adaptability from the contemporary population to prepare for the subsequent steps. The purpose is to save the good individuals and eliminate the inferior individuals and make the algorithm converge. The elitist selection method enables every generation of the population to have the best individuals from the early generation to the present generation. The specific way of operation is to directly select the best individuals of the current group to the next generation, so that the best individuals cannot be destroyed by crossover and mutation operations. In addition, elite selection can be extended to directly select some of the current group members to the next generation without cross or variation. But using the elites' selection method alone may cause the whole algorithm to converge to the local solution and lose the original intention of the global search, so it is usually used together with other options.

Control parameters have a significant impact on the performance of genetic algorithms, which are usually determined at the initial stage of the algorithm. The main parameters are population size, maximum genetic algebra and termination condition, individual length, crossover and mutation probability. The population size, that is, the number of individuals in the population, provides the solution space for the algorithm and prevents premature convergence. But too large population size will increase the computation cost and speed up the solution. The maximum genetic algebra and termination conditions are the conditions for the end of the algorithm. The length of individual is determined according to the problem of solving. To improve the efficiency of the algorithm, it is better to take a smaller length when meeting the parameter requirements of solving the problem. The probability of crossover and mutation is too high, which may destroy many excellent individuals and reduce the overall goodness of population, thus increasing the number of iterations. The crossing probability is too low, which may result in a local optimal solution. For fixed cross probabilities, it usually lies in the interval of [0.6, 1). If mutation probability is too small, the diversity of the population will be reduced. Too much will destroy the excellent individuals too much, so the fixed mutation probability lies in the interval of [0.005, 1).

3.3 Algorithm improvement

With the improved crossover and mutation probability, the convergence rate of the optimal individuals is improved. To further improve the convergence speed is beneficial to reduce the calculation load of the regional centralized control machine. Therefore, the optimal period and phase time of the intersection can be calculated by each intersection control machine separately, while the best part of the last generation population is retained, and this part of the individual combination can be combined when the parameters of the centralized control machine are transferred to the regional centralized control machine. As an initial population for calculating the optimal period and phase time of the region and limiting the period to the minimum and maximum of the period passed at the intersection, it is beneficial to improve the convergence rate of the optimal individual in the regional calculation and to reduce the load of the centralized control machine. The delay index DELAY is a problem of minimum value, which is solved by genetic algorithm. It needs to be transformed into the problem of maximum value. The calculation of the delay is transformed into the calculation of the fitness in the algorithm.

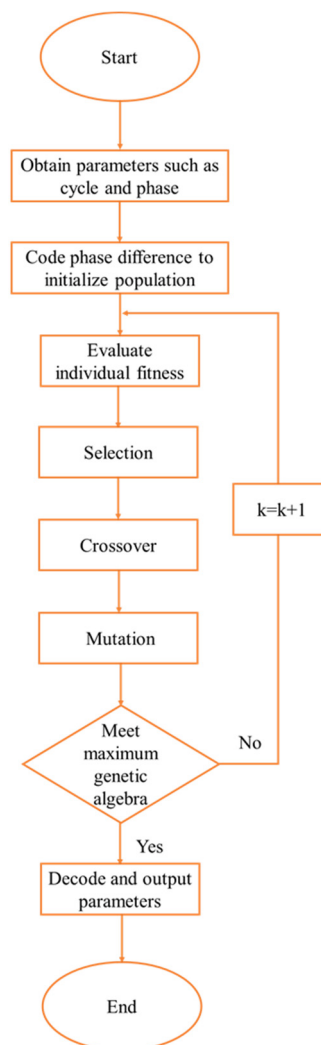


Figure 1. Flow chart of timing optimization of regional traffic signals based on improved genetic algorithm

4. Example verification of timing optimization of regional traffic signals based on improved genetic algorithm

Taking the road intersection along the main road as an example, we investigate and study the collected data, prepare for the later model verification, and combine the model established in the fourth chapters to select the two continuous Road intersection as the research object. C1, C2, C3 and C4 are typical cross sections. The main road does not carry out motor vehicle and non-motor vehicle branch, the branch is a narrow section form of a piece of plate, which is separated by setting isolation fence in the middle of the road. Investigating the traffic status of the above research objects, the implementation of the current traffic signal control scheme causes the following problems. The traffic flow at the road intersection varies greatly, and the traffic volume is large in some time periods, especially when the traffic flow of the secondary road enters the trunk line. The bus stop affects the stable operation of the main road traffic flow. The traffic and traffic flow of schools, hospitals and other units along the road have no control and affect the traffic flow of main roads. In the early peak period, the traffic flow in the region is obviously increased, the key intersection is more, and the cycle length of each key intersection is adjusted to the maximum, and the green signal ratio of the correlation phase of the upstream intersections is also reduced. Therefore, the traffic signal control parameters in the area can be optimized to cope with the supersaturation in the rush hour. The situation in the late peak is similar to it.

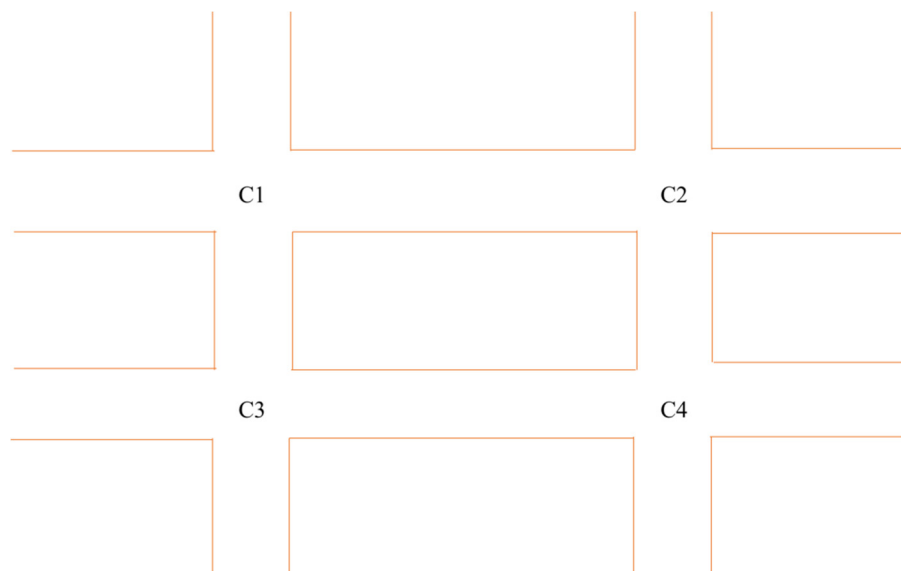


Figure 2. Crossroads of empirical case

In the condition of supersaturation, traffic congestion and queuing are the most important problems in urban traffic system. Therefore, the maximum crossing rate is the first goal to optimize the parameters of traffic signal timing. By adjusting the length of the intersections and the time of the green light, the traffic conflict or signal control is referred to. The time loss caused by the limited facilities is an important parameter to measure the effect of the intersection, and it has important reference value in the performance evaluation of the signal control system. In this paper, the control delay is used to analyse the intersection traffic delay analysis. The control delay is the difference between the time required by the free flow speed through the intersection and the actual passing time of the vehicle under the control of the vehicle's signal control. The overall efficiency of the key intersection in the sub region has been improved significantly, while the traffic efficiency of the upstream intersections has been reduced, but the overall efficiency of the region has been improved. In this paper, the optimization method of regional signal timing parameters under the condition of supersaturation is carried out by adding the traffic carrying capacity of the inlet channel of the key intersection and reducing the traffic capacity of the upstream intersection, to optimize the signal cycle length of the intersections and the phase green time to realize the traffic signal control under the condition of supersaturation. The improvement of regional

overall traffic efficiency shows that the optimization method of regional signal timing parameters under supersaturation has a significant effect on improving the overall regional traffic efficiency under the condition of supersaturation. The results are shown in Table 1.

Table 1. Timing optimization results of genetic algorithm and improved genetic algorithm

Corner	Genetic algorithm		Improved genetic algorithm	
	Phase time (s)	Period (s)	Phase time (s)	Period (s)
C1	36, 39, 42, 38	125	31, 32, 28, 33	117
C2	35, 35, 36, 35		25, 29, 31, 28	
C3	36, 44, 41, 38		36, 31, 31, 39	
C4	41, 38, 38, 39		33, 25, 34, 27	

5. Conclusions

Based on the improved genetic algorithm, the optimization scheme of regional traffic signal timing is given in this paper. The main conclusions are as follows:

- (1) The basic models, common parameters and evaluation indexes of the traffic signal control theory are given in this paper.
- (2) The paper points out the advantages and disadvantages of genetic algorithm in the timing optimization scheme of regional traffic signal, explores the optimization scheme based on the improved genetic algorithm in regional traffic signal timing and draws the corresponding flow chart.
- (3) Practice has proved that the improved genetic algorithm is superior to the genetic algorithm in the convergence speed of regional traffic signal timing optimization.

Acknowledgements

This work was supported by the Shenzhen Science and Technology Program (Grant No. JCYJ201508311922241 46).

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