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A GA based Intelligent Traffic Signal Scheduling Model

Shaw C. Chang, Ming W. Tsai, and Gi W. Huang

***Abstract*—A GA based intelligent traffic signal scheduling model is proposed in this paper. There are two layers in this model. The upper layer decides which direction of intersection should have the priority to go. The intersection signal controller in the lower layer will execute its instruction. The upper layer has to make a decision in a very short time limit, or the signal in the lower layer will response to a wrong traffic pattern. It is as if what the fixed time signal scheduling strategy did before. This paper shows this idea through a simulation model. Our simulation results show that it saves 71 seconds from the fixed time signal scheduling strategy. The lost time might be even higher in our real world. If one intersection is jam-packed, our simulation result also shows that all cars will be redirected within a short time. This model can bring the travelers a better experience of traffic facility for keeping their transportation efficient.**

I. Introduction

THE time phase in the signal controller was set according to the investigation of the traffic volume in the road network. If the intersection is jam-packed due to some festivals or celebration events, all information surveyed previously cannot be applied to this unusual event, as the Origin-Destination, OD, of a traveler is changed. The objective function of the traffic signal scheduling strategy should also be changed accordingly. It cannot be the delay of traveler all over the network as usual since the intersection performance is much more important at that time. Meanwhile the calculation time of the signal scheduling strategy must be fast enough to respond the traffic in a local area to avoid controlling the traffic signal by a police officer. The drawbacks of a traffic-responsive signal controller at an isolated intersection are that it does not have the information of other intersections within a local traffic network and it is not efficient to be used when the traffic flow is huge. Even it does have the information. The responding time will not be fast enough for the need of the traffic in such network. The condition will be even worst if the traffic does not follow the traffic signal. Of course, these will increase the delay of traffic dramatically.

Therefore, we do need a higher layered model to raise the isolated traffic-responsive signal controlling structure to behave as a network-wide traffic-adaptive signal scheduling architecture. That is an intelligent traffic signal scheduling model. If the signal controllers at all intersections in this area have both the fixed time and the adaptive control mode, the upper layer model will have the information over the entire traffic network and decides which direction at the intersection in this area should activate the green light. Thereafter, it will pass the result to the signal controller at all intersections. It is just like whenever the president passes through an area. There will be many police officers located at each intersection along with the route of the president. They will communicate with each other if the president will pass the intersection, like the work in upper layer model. The police officer will then adjust the signal controller according to his knowledge about the intersection, which is the operation of lower layer model. In this way, the system performance can be improved if an upper layer model makes the decision. This architecture will be more efficient if the abnormal condition occurs, such as a jam-packed intersection.

The model we built here focuses on the upper model and try to handle this situation flexibly either in normal or abnormal condition. The genetic algorithm is applied to solve the real time optimal signal timing problem in a traffic network, where includes 26 intersections we used as an example in this paper. The goal of this model is to decrease the waiting time of all cars after the stop line at every intersection in this network. Most important of all, this model is very easy to simulate the situation at the intersection when it has been jam-packed. It just needs to click at the intersection with mouse on the network-monitoring screen and all cars around this intersection will drive back to the last intersection where it just came from. All these conditions can be simulated from a user interface very easily.

Most of the literatures in signal control are focused on the isolated intersection signal control strategy. Such as Miller's Algorithm [8], Traffic Optimization Logic [1], MOVA [14], SCOOT [11], LHOVRA [9], OPAC [2], SAST [7], COMDYCS-III [4, 5, 6]. This kind of model does not have to consider the traffic flow of other related intersections. Its control logic can also be designed and dedicated to the specific intersection only. To achieve the minimal cost in this area, there needs an upper layer model to give the signal an indication to schedule the movement of the traffic flow at all intersections.

The network based adaptive signal control model, such as SCOOT, SCAT [12], and PRODYN [3]. These models are based on the optimization of cycle, split and offset. The non-cycle based adaptive signal control is rare in the literature.

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S.C. Chang is with Institute for Information Industry, Taipei, TAIWAN, R.O.C. (phone: 886-2-27368088-5121; fax: 886-2-27368022; e-mail: scchang@iii.org.tw).

M.W. Tsai is with the Department of Information Management, Cheng Chi University, NO.64, Sec.2, ZhiNan Rd.,Wenshan District,Taipei City 11605,TAIWAN, R.O.C. (e-mail: 94356503@nccu.edu.tw).

G.W. Huang is with Institute for Information Industry, Kaohsiung, Taiwan, R.O.C. (e-mail: gwhaung@iii.org.tw).

The model presented in this paper can point a direction to study this topic further.

About the abnormal condition, [15] has studied on the strategy of isolated intersection of incident responsive signal control with system dynamic model. Ting [13] has extended her result to a coordinated signal system. With the concept of network adaptive signal control model, if it makes decision by considering the cars waiting after the stop line, then the system will give the congested intersection more opportunity to evacuate. This might lower down the complexity of the above two models.

The model in this paper consists of the characteristics of the above three issues. It can adapt the advantage of isolated intersection adaptive signal control, practice the idea of non-cycle network based adaptive signal control, and contain the ability to handle the abnormal operation.

II. Problem Description

The network layout in this paper is in Fig. 1. There are twenty-six controlled intersections in this area. The attributes of each road is two-lane two-way. Since it is the network wide controlled layer, it does not need very detail and accurate information. The car movement can be treated as a single car or a platoon. For the purpose of simulation, we generated the distance shortest path of each car between the assumed origin

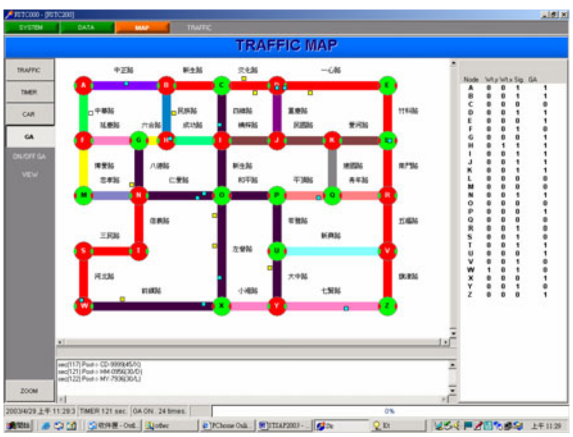

Fig. 1. Traffic Network layout.

and destination. As the traveler will always plan their route based on their knowledge about their interested area before their trips occurs. The simulation of shutting down the intersection just needs to click the intersection with mouse on the network-monitoring screen of the software and all cars around this intersection will return to the last intersection where it just came from. While the simulation starts, all cars depart from their origin. By following their default speed, network layout, their expected path, and the indication of signal on their route, this simulation stops whenever all cars reach their destination.

In this paper, we define the optimization function as a combination index of several soft constraints. Therefore, our goal is to find a solution, which can minimize the objective function in an acceptable period, like a second. The soft constraints considered in this paper include,

1) $WaitingCarEW_{S_i}$: the cars waiting in the east-west direction at intersection S_i.

2) $WaitingCarNS_{S_i}$: the cars waiting in the north-south direction at intersection S_i.

If there are N intersections in this area, the objective function is then defined as the soft constrain, like "(1),"

Objective Function

$$= \sum_{S_i=1}^{S_N} (WaitingCarEW_{S_i} + WaitingCarNS_{S_i}) \qquad (1)$$

III. Problem Solution

A. Solving logic

The fixed time signal is efficient while the traffic flow is huge in both directions. The adaptive signal control will have its effect under the middle to low traffic flow. To handle the abnormal condition, integrating those two modes will be a good idea to consider the performance and flexibility. That is why we assume that each signal controller of all intersections in this area has both the fixed time and the adaptive control mode. Normally the signal operates the fixed time mode. Once the car approaches the intersection, the adaptive control mode will be active and then decides which intersection will allow the stopped car to move forward, like Fig. 2.

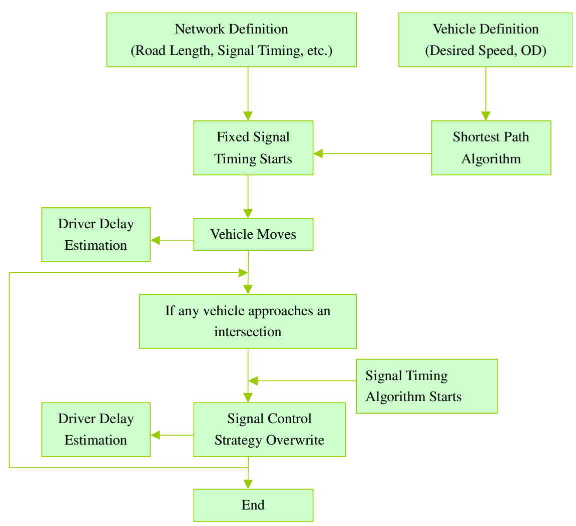

Fig. 2. The intelligent traffic signal scheduling logic.

If the intersection is closed, the route of every car passing through this intersection will be re-calculated. The control logic shows in Fig. 3. It can operate the same model to deal with this circumstance.

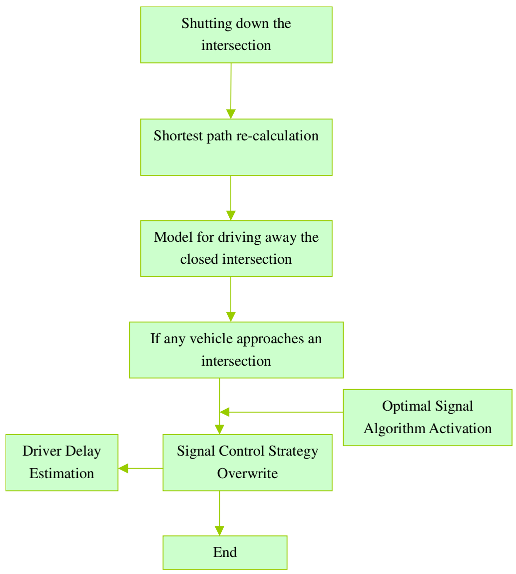

Fig. 3. The intelligent signal scheduling logic for a closed intersection

The operation logic is illustrated as the following Fig. 4,

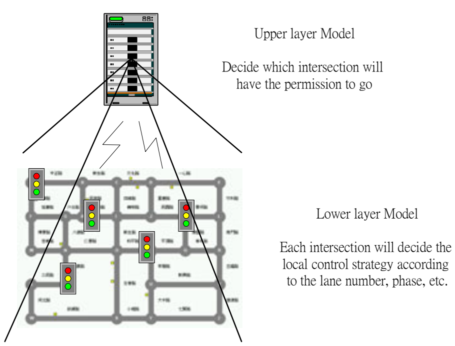

Fig. 4. The two layer intelligent signal scheduling model.

The upper layer decides which direction at the intersection can move forward. The lower layer will receive the result sending from the upper layer and make the detail control over the intersection. This helps for improving the performance of signal control system and reducing the social cost of the travelers.

B. GA based model

In this paper, the upper layer tries to adjust the signal of every intersection to minimize the number of cars waiting after the stop line at the intersection in this area. The function of this model is to receive the status of the signal at the intersection and make the optimal signal decision according to the number of waiting cars at the intersection. Thus, the computation time is less than a second and can be operated on time just as the simulation in this paper. Genetic algorithm provides the mechanism of generating the solution, testing how good it is, and improving the solution generation by

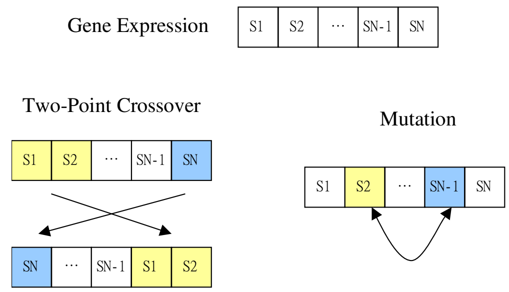

Fig. 5. The GA operators.

generation. It is very suitable for us to find the solution. As for the chromosome encoding method, there are many GA encode styles presented in GA community, such as binary string style, tree style, etc, [10]. In this paper, we use binary string style to represent the status of all signals. Fig. 5 shows the binary encoding method. The number of intersection defines the length of the bits used in a chromosome. The upper layer will decide which direction will have the green light. If the north-south direction of intersection S_i has the red light, then the value of S_i is one, otherwise, 0.

Fig. 5 also shows the method for crossover and mutation. The two-point crossover is adopted in our GA system. It randomly selects two cells and swaps the contents of head and tail. The mutation method is to select two different cells randomly. Then swap the content of those two cells.

C. The result

The simplicity of the model can determine the intersection strategy in less than a second. This real time decision can fit the requirement of adaptive control since the control logic has to make a decision on time. This objective function of the model does not include any constraints. Thus, there will be no infeasibility problem in this case. To test our idea, we not only built an upper layer network signal control model, but also the car monitoring simulation model to test its performance. To show the effect of our model, we can compare the results between the following two simulations. One runs with the fixed time mode. Another runs with the combination mode between fixed time and adaptive control. That is normally running with fixed time mode. If any car approaches to the intersection, the adaptive mode will be activated. It will apply the GA to evacuate all cars in this network as soon as possible. The GA will be activated again if another car approaches to the intersection and running with another thread. Its computation is less than half second. Therefore, it will not affect the system performance.

To check the performance of the upper layer model, we can compare the evacuation time between two scenarios under the same car attributes and road layout as shown in the case 1 of the TABLE I. The simulation without GA needs 234 seconds to evacuate all cars in this network. However, the simulation with GA only needs 163 seconds to evacuate all cars in this network. From this simple comparison, you can realize that if the signal controller runs with fixed time mode, then in such a simple case we will spend about 71 seconds waiting this

TABLE I
THE TRAFFIC INTENSITY AND THE TIME TO EVACUATE ALL CARS

Case	Evacuation Time with adaptive	Evacuation Time with fixed time mode
1	163	234
2 (O)	167	239
3 (G)	182	245
4 (C)	167	257
5 (N)	345	489
6 (I)	166	250

unwise signal scheduling strategy. From the following Fig. 5 you can see the influence of car movement with or without GA very clearly. A signal scheduling strategy with fixed time mode fail to give driver the right to pass the intersection even there is no car in another direction.

In this paper, we can also check the effect of shutting down

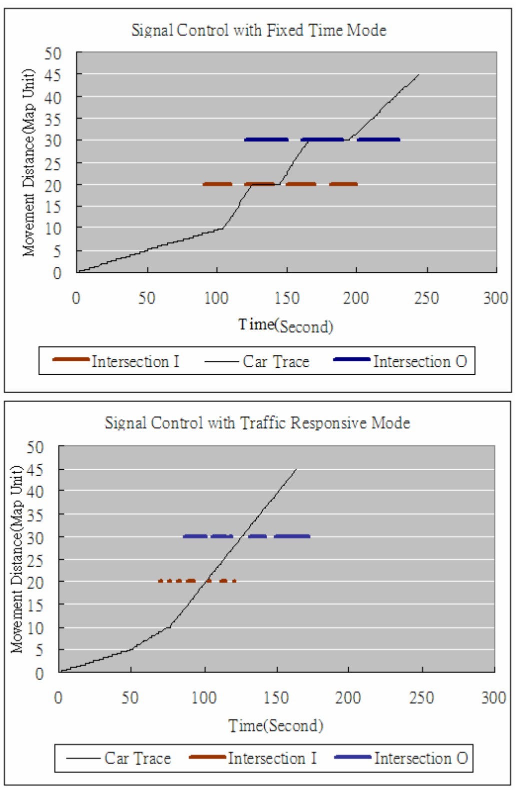

Fig. 5. Illustration of the car movement between two signal-scheduling strategies.

the intersection. We select several different intersections to see what will happen in these conditions. Case 2 simulates the intersection O of being shutting down. Case 3 is G, etc. The time to evacuate all cars is shown as in TABLE I.

As the intersection is shutting down, the traveling distance of some travelers will be longer than before. The evacuation time of all cases is longer than no intersection has been closed. Some travelers will suffer even worst if the closed intersection is on their critical path. They have to travel further than their original routes.

IV. CONCLUSION

In this paper, we have proposed a framework of intelligent traffic signal scheduling strategy and used the simulation model to proof its effect. The upper layer of the GA based two layer traffic-adaptive signal scheduling model will have the information over the traffic network and decides which direction of intersection in this area should have the priority to evacuate. It will then pass the result to the intersection signal controller. The network information will be more important if some intersection has been congested. This paper shows this operation through a simulation model. In addition, the workload of lower layer signal controller will decrease to execute only the decision of upper layer. This improves the system performance. This real time decision is critical in the traffic-adaptive signal control since the signal strategy has to response the current traffic condition.

The simulation with the intelligent traffic responsive model only needs 163 seconds to evacuate all cars in this network. That is 71 seconds saving from waiting an unwise signal control strategy. We can hardly image how much time is lost in our real world. From TABLE I, the other simulations also demonstrate the huge saving if the intersection running with traffic responsive model, especially when some intersections were shut down. From the view of Intelligent Transportation System, travelers deserve a better service of traffic facility. The cycle of the intersection with fixed time mode falls between 30 and 60 seconds. If the intersection designed with long cycle then the traveler will waste more time on their drive.

The performance of upper layer depends only on the size of intersections. This can be controlled much easier than the prediction of traffic volume of all approaches in the intersection. To see other applications of our model, some scenarios, like more intersections, heavy traffic flow around this area, and long cycle signal, etc, can also be simulated and examined in the near future.

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