Time Optimization for Real Time Traffic Signal Control System Using Genetic Algorithm

G.N Purohit
Emeritus Professor, Dept. of Mathematics & Computer Science, Banasthali University, Banasthali
gn_purohitjaipur@yahoo.co.in

A.M Sherry
Professor & Director (IMT-CDL) Institute of Management & Technology, Ghaziabad, (U.P)
amsherry@imt.edu

Manish Saraswat
Assistant Professor, Department of MCA, Geetanjali Institute of Technical Studies, Udaipur, (Raj.)
manishsaraswat24@gmail.com

ABSTRACT

In this paper, a "real-time" traffic signal control strategy is provided using genetic algorithms to provide near optimal traffic performance for intersections.

Real-time traffic signal control is an integral part of the urban traffic control system and providing effective real-time traffic signal control for a large complex traffic network is an extremely challenging distributed control problem. The developed "intelligent" system makes "real-time" decisions as to whether to extend green time for a set of signals.

The model is developed using genetic algorithm implemented in MATLAB. A traffic emulator is developed in JAVA to represent dynamic traffic conditions. The emulator conducts surveillance after fixed interval of time and sends the data to genetic algorithm, which then provides optimum green time extensions and optimizes signal timings in real time.

The optimization parameters are - total number of vehicles in a road and importance of the road in the intersection. In the end, by comparing the experimental result obtained by the fixed time and real time based traffic systems which improves significant performance for intersections, we confirmed the efficiency of our intelligent real time based control system.

KEYWORDS

Intelligent System	Traffic Emulator	Genetic Algorithm

PREAMBLE

The increase in urbanization and traffic congestion creates an urgent need to operate our transportation systems with maximum efficiency. One of the most cost-effective measures for dealing with this problem is traffic signal control.

Traffic Signal Control is a system for synchronizing the timing of any number of traffic signals in an area, with the aim of reducing stops and overall vehicle delay or maximizing throughput. It provides control, surveillance, and maintenance functions i.e. control of traffic by adjusting and coordinating traffic signals at intersections, surveillance by monitoring traffic conditions with vehicle detectors and cameras; and maintenance of equipment by monitoring for equipment failures. These functions allow a traffic management agency to service traffic demand, share traffic status with other agencies and operate and maintain the traffic signal control system.

Traffic signal control varies in complexity, from simple systems that use historical data to set fixed timing plans, to adaptive signal control, which optimizes timing plans for a network of signals according to traffic conditions in real time [1].

Although traffic signal control has been studied for many years, it remains an active research topic. A summary of recent advancements is provided in [2].Kirschfink et al. introduce intelligent models to catch as much as possible from vehicle traffic features [3]. Papageorgiou et al. give an overview of the main traffic control problems and their approach methods [4]. Some studied the reserve capacity of a road network under fixed time traffic control [5].

Hong & Lo [6] developed a methodology to analyze the Phase Clearance Reliability (PCR) of a signalized intersection and describe the performance of traffic signal.

Han & Zhang [7] proposed an approach to detect and count vehicles at an intersection in real- time to increase efficiency on traffic control.

In this paper, we developed emulator for representation of traffic conditions at an isolated intersection with the following silent features: Graphical User interface (GUI) developed in JAVA, random generation of vehicles, random vehicular direction, collision avoidance, and traffic signals with fixed phase sequence, surveillance of traffic conditions(stopped vehicles) at specified intervals, traffic signals with minimum green length duration. Genetic algorithm is used for traffic signal timing optimization.

Factors considered for genetic optimization are weights allotted to each road (depending upon their usage and traffic capacity etc), fixed maximum and minimum green timings, fixed cycle timings and total stopped at each incoming lane.

The Figure 1 shows the traffic flow behavior in the network depends on control inputs that are directly related to corresponding control devices i.e. traffic lights, variable message signs, and disturbances etc.

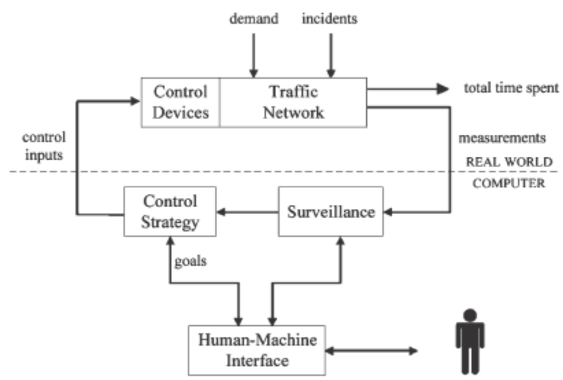

Fig:1: Modeled Diagram of Traffic control System

The function of the control strategy module is to specify the control inputs in real time based on available measurements (e.g. from loop detectors or traffic cameras). Surveillance system provides real time status to the control algorithm which decides control inputs. A human interface is required to monitor the control strategy [8].

MODELING TRAFFIC EMULATOR

The traffic emulator is modeled to implement a fully concurrent emulator of cars and traffic signal lights interaction at an intersection. Traffic emulator consists of a four legged isolated inter section with corresponding four traffic lights for controlling straight and right turn traffic, while the left turn is free. The car generation speed and car speed can be changed as per desired.

COLLISION AVOIDANCE

Collision avoidance is implemented by the concept of locks. A lock is a fixed sized space that can be occupied by a car. A car can occupy a lock ahead of it only if it's unoccupied and the signal is green if it is the first car in the lane.

Similarly, while turning, before moving, a car must grab all lock objects it needs, otherwise, it will be blocked. The traffic emulator implements fixed cycle length and fixed phase sequence to ensure that all the roads gets their turn and no road is neglected for a very long time.

The emulator conducts the surveillance and sends the data to the control algorithm for evaluation. Traffic light management at an intersection is an extremely challenging and complex. Normal traffic behavior even though seems pretty normal, is however extremely difficult to predict & simulate in an artificial environment.

The number of different factors affecting the sequence and duration of traffic light signals can be very wide. Several assumptions had to be made, in order to reduce the overall Complexity. The various assumptions made are as follows:

(i) The intersection is assumed to be relatively "busy" and under-saturated with significant demand variations in all the approaches.
(ii) The intersection is assumed to be four-phased with a phase for each approach.
(iii) The phase sequence does not change from cycle to cycle.
(iv) The cycle time remains fixed.
(v) All cars are assumed to have same speed.
(vi) Cars can take a free left turn provided they do not have a vehicle in front. There are no unnatural traffic situations such as accidents, disruptions etc.

MODELING TRAFFIC CONTROL PROBLEM

The current Traffic Management system is designed scientifically but usually fails to provide an optimum throughput of vehicles through an intersection. Providing effective real time traffic signal control for a large complex traffic network is an extremely challenging distributed control problem.

We aim to develop an efficient traffic adaptive control strategy that identifies the real time traffic scenario in small steps (surveillance interval), and gives appropriate green time extensions to minimize a fitness function consisting of linear combination of performance indexes of all the four lanes .

Fitness function, f = P.I.1 + P.I.2 + P.I.3 + P.I.4

The Performance Index (P.I.) for each road depends upon

weight of the each road (i.e. capacity of the road and priority of the road assumed same), the total number of vehicles on the road given by S. S = S1 + S2 + S3 +S4 Performance Index (P.I.i) = Wi * Si /GTi i=1,2,3,4; where Wi is weight allotted to road i respectively; Si is number of vehicles at road i respectively; GTi is sum of minimum green time (Gmin) and green extension time (g).

PROPOSED SOLUTION TO THE PROBLEM

USING GENETIC ALGORITHM

A Genetic algorithm (or GA) is a search technique used in computing to find true or approximate solutions to optimization and search problems. MATLAB Genetic algorithm application interfaces are used to implement the algorithm.

The Genetic algorithm is constrained with a fixed cycle length of 70sec and green extension times (g) with the bounds of 0 to 5 seconds. g1 + g2 + g3 + g4 – 10; where (gi represents green extension time, i=1, 2, 3, 4) and 10 is total extension time of the entire signal.

Gmin = 15sec (Fixed green time for each road).

G.T. = Gmin + x (Green time allotted to the road).

The surveillance data from the emulator is sent to GA. They produce a set of green time extensions, which minimizes the fitness function, simultaneously satisfying the constraints.

The Figure 2 illustrates the process schematically as follows:

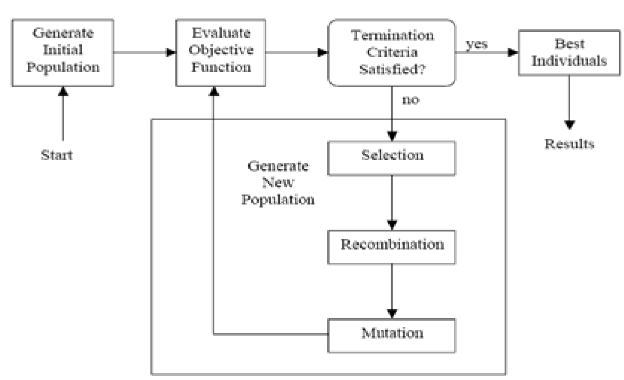

Fig:2: implemented Genetic Algorithm

(1) An emulator is developed which shows dynamic conditions of traffic on an isolated four-way intersection.

Code for surveillance is written which gives the total number of cars on each road in the intersection.

(2) After each predefined surveillance interval, genetic algorithm is executed with the input as total number of cars on each road as determined by S.

(3) The Genetic algorithm (GA) executed as to obtain the best possible solution. The steps of algorithm are as:

(i) Generate the random population (i.e. green time extension) which is selected by a random function within the specified range (0-5).

(ii) Evaluate objective function (i.e. fitness function used). The fitness function is to be minimized (i.e. it gives small values for better generations) .

(iii) Check, if termination criteria is satisfied (i.e. either the predefined maximum number of generation have reached or fitness function is not satisfied, the performance is tested with both 100 and 6 generation.

A small improvement in case of 100 generation is observed but to increase the speed of algorithm, 6 generations have used). (iv) If the termination criteria are not satisfied; selection is performed from the given population to obtain fitter parents, which can lead to fitter sons.

(v) These parents, thus selected are mated to produce fitter children and this phenomenon is called crossover or recombination.

(vi) Some mutation is performed (i.e. some bits of children are altered from the above result). This emulates the real life as children may have some traits different but the chances are generally kept very low.

(vii) After mutation we have a new set of generation, now go back to step (ii).

(viii) If the termination criteria in step (iii) are satisfied, get the solution (i.e. the current generation).

(4) The result is received from GA is the green extension times for all the four roads. These extension times are added with predefined fixed green times and applied to the emulator.

SIMULATION RESULT

In this section, we compare the results obtained by proposed real time based system with traditional fixed time system. Both the systems are tested on the setting of fixed green signal time of 15 sec. , with a green extension of up to 5 sec. in case of real time based system.

The comparison parameter considered is the total number of exit vehicles at a fixed car generation speed and car speed settings for fixed intervals of times. The results obtained are as follows: for car generation speed of 200 ms and car speed of 200 ms is given in Table I.

The sample results shown in Table I gives the output of 573 vehicles and 662 vehicles in the case of fixed time based system and real time based system respectively thus showing a significant performance increase of 21.9 % in case of real time based system.

CONCLUSION

In this paper, an “intelligent” isolated intersection control system was developed. The developed intelligent” system makes “real time” decisions as to whether to extend (and how much) current green time. The system applications appear to be very promising. The system shows significant performance improvement compared to fixed time based system within experimental limits (computation power, random path selection, emulator settings) under the given assumptions. The model developed is based on the genetic algorithm, which optimizes traffic signal timings in real time and provides a set of optimum green time extension for all the four phases depending upon the surveyed traffic conditions.

Time (in min.)	Out Traffic (Fixed Time System)	Out Traffic (Real -Time Based System)
1	30	37
2	75	73
3	120	141
4	158	181
5	190	230
	Total: 573	Total: 662

Table: 1: Comparison Between Real Time & Fixed Time Systems

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