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Optimization of Traffic Flow through Signalized Intersections using PSO

[1]Parag Hirulkar, [2]Rahul Deshpande, [3]Preeti Bajaj *Senior Member IEEE*
[1]Research Scholar, [2]Prof. Civil Engineering [3]Prof. Electronics Engineering
G. H. Raisoni College of Engineering, Nagpur, India.
[1]plhirulkar@gmail.com, [2]rahul_deshpande@msn.com, [3]preetib123@yahoo.com

Abstract-- **Traffic signal operations play an important role in the effective functioning of an urban area. They allow utilization of the existing resources to their maximum potential, which is particularly relevant today as funding sources are scarcer than ever. The objective of this research is to develop an effective procedure to optimize intersection signal timing, cycle length, splits & offsets by minimizing total delay. In this research we will utilize Particle Swarm Optimization (PSO) Algorithm for traffic signal timing optimization problem. A new particle swarm optimization algorithm is proposed to minimize the average delay and average number of stops for adjacent junctions and to handle the constraints. An actuated traffic control strategy will be employed to calculate the green time for each phase in a traffic-light cycle. The simulation results show that the delay per vehicle can be substantially reduced under constant traffic demands and time-varying traffic demands by suitably adjusting traffic signal timings. The implementation of this method does not require complicated hardware, and such simplicity makes it a useful tool for offline studies or real-time control purposes.**

Keywords—Actuated traffic control, Particle Swarm Optimization (PSO), Real time control, Time-varying traffic.

I. INTRODUCTION

Intersection as the city's road network node is the meeting point for distribution of traffic flow. In fact, as population is growing it worsens traffic congestion. It takes lot of time to clear road congestion. Again due to urbanization less room is left for the city planners to device new measures to accommodate the ever-increasing road-traffic demand. Traffic control at a road junction involves assigning green time to each phase of the traffic. Effective and coordinated traffic control may be an essential tool for relieving the congestion to ensure the safe passage of vehicles, to minimize delay and to maximize junction utilization by modifying and implemented at any traffic light junction.

Traffic signal control mainly falls into two categories: fixed-time and traffic responsive control. In fixed time control technique the green light timing is fixed for all the junctions whereas in traffic responsive control time varying traffic the green time for each phase in a cycle is changed depending upon the traffic volume.

A. Single-Junction Control

Single-junction signal control mainly falls into two categories, fixed-time and traffic-responsive control. The former is a static optimization based on the statistics of the past traffic-flow patterns.

A fixed-time control system is simple in structure and does not require any vehicle detection in the vicinity of the junction. The lack of input of the real-time traffic condition is, however, a major drawback of a fixed-time controller, as it is incapable of responding to any unexpected changes in traffic demand. Hence, a fixed-time controller needs to be reevaluated and recalibrated regularly. Updates of control plans are based on collection and projection of traffic data. Since it is not practical to collect the data on a daily basis, a simple model of traffic growth, such as linear increment, is usually assumed. This is to ensure that the traffic plan is sufficient to deal with traffic growth over a period of time.

SIGSET has been one of the commonly used systems for fixed-time control plans. A signal cycle is divided into a number of phases that allow traffic from different directions to pass through with specific green time. SIGSET determines the optimal green time at each phase and the cycle time, while the sequence of the phases is fixed. Extensions to allow different phase combinations are possible [1], which leads to more complexity in the optimization.

Traffic-responsive control is an online process that takes real time traffic data as input and optimizes the green time at each traffic light, according to the current traffic conditions. At the expense of extra hardware cost, mainly on detectors, traffic responsive control provides the ability to adapt to real-time traffic variations. The availability of real-time data also enables the control to be extended to meet different performance criteria, such as minimization of stops, fuel consumption, or exhaust emission rate for the whole road network or subareas within the network [2].

Early research in traffic-responsive control [3], [4] focused on traffic flow or demand prediction. The philosophy was to predict what the demand would be in the next few traffic light cycles and to optimize signal settings according to the predicted demand. However, difficulties in reliable flow prediction resulted in the failure of these early approaches. Another traffic-responsive approach requires the calculation of control parameters according to prevailing traffic conditions and the dynamical adjustment of cycle time and phase split [5].

B. Coordinated Control with Connected Junctions

Junction coordination involves organizing the timing of the traffic signals at adjacent junctions, in such a way that when a vehicle reaches a junction from another, the driver encounters a succession of green signals and need not to stop or slow down. The traveling time from one junction to another is, therefore, the optimal signal offset between the two junctions, if they have the same cycle time. Effective coordination can, of course, shorten queues and reduce delays. It has been proven that effective signal coordination reduced the average queues by four to ten vehicles with an onsite experiment [6]. Coordination of traffic signals in a road network should take into account the cycle length, phasing split, and offset of all signals in a road network, hence leading to a reduction in the average delay or the number of stops. However, determining the signal offset is not always simple in reality.

Fixed-time control is also available with connected junctions [7], [8] and it attempts to prescribe the signal settings in such a way that the traffic, particularly on a main or arterial road, proceeds without stopping at any signal, as much as possible. Again, having relied on historical data to formulate the signal settings, the fixed-time approach is not relevant to traffic dynamics, but it is applicable to unsaturated traffic.

The traffic-responsive approach follows the concept of decentralized control, in which each single junction is regarded as an individual unit and looked after by a local controller. Every junction controller is responsible for coordination with its adjacent junctions by exchanging information like current phase, green time, and queue lengths. After gathering all the information from adjacent junctions, the controller makes decisions on the extension of the green-time period. One of the advantages of decentralized control is that the computational demand is more manageable, because of the distribution of computation to local controllers.

We proposed a particle swarm optimization algorithm to optimize the traffic control signal on road-junction traffic system in this project. Particle Swarm Optimization (PSO) is a population-based algorithm. The cycle length, the phasing splitting and offset of all signals in the adjacent junctions system are optimized using the new PSO algorithm.

Estimated delay is used as the principal measure of the level of service at signalized intersections. The reason for this is clear: Delay can be measured and it is very easy for not only the engineer but the driver to understand the concept of delay. Indeed, environmental awareness prompts drivers to eliminate unnecessary stops and shorten journey time. Effective and coordinated road-junction control can certainly help this cause.

II. REVIEW

This paper reviews the road-traffic control strategies and methodologies. A local controller has been developed for individual junctions and it provides the basis for this coordinated control. The performance of the coordinated control is evaluated through CORSIM and MATLAB simulation.

In transportation systems techniques, such as [10], [11], [12], [13] etc. these studies showed a certain degree of success, particularly when the traffic is not heavy and the turning percentage is small. However, when traffic is heavy, more phases have to be introduced to the cycle to cater to the turning traffic. In [14] a decentralized approach on road-junction traffic control is proposed, a local controller is installed at each junction and a dynamic programming (DP) technique is proposed to derive the green time for each phase in a traffic cycle. These works are capable of handling junctions with turning traffic. But it has been pointed out that DP method in [14] does not always produce the optimal control actions even though it improves the traffic control performance in general, and the computation time required by the DP technique takes nearly double of the time for fixed-offset control coordination, which make it not particularly efficient in large systems.

Swarm intelligence is based on the social behavior of flocks of birds/schools of fish and the success of the swarm due to the communication established between them. Particle Swarm Optimization (PSO) originally developed by [14], [15], which is a population-based algorithm. PSO is initialized with a population of candidate solutions. Each candidate solution in PSO, called particle, has associated a randomized velocity, moves through the search space. The PSO has been found to be robust and fast in solving nonlinear, non-differentiable, multimodal optimization problems.

Dong et al [17] developed Simulated Annealing Particle Swarm Optimization (Sa-PSO) algorithm based on particle swarm optimization (PSO) and simulation was carried out in a nine-intersection network and the result shows that the use of Sa-PSO method can reduce 41.0% of the average delay per vehicles, and 30.6% of the average stop rates comparing with fixed time plans. But the research of Sa-PSO as just at the beginning, there were still so much problems for further study.

We propose a decentralized approach with particle swarm optimization algorithm to optimize the traffic control signal on road-junction traffic system in this study. Each junction is equipped with a local controller to allocate the green time for each phase in a cycle, the standard PSO algorithm is used to optimize the functions. Some initial solutions are provided for the new particle swarm optimization algorithm. The cycle length, the phasing splitting and offset of all signals in the adjacent junctions system are optimized using the new PSO algorithm and the coordination parameter confining the possible control space. The assignment of green time to each phase of a traffic cycle is considered as a multistage control problem with a finite number of possible control actions at each stage.

The objective of the PSO learning algorithm is to minimize average delay D of vehicles in all traffic streams (resource allocation) and to maximize the number of vehicles C leaving the junction (resource utilization).

III. EXPERIMENTAL SETUP

A simple network of five connecting junctions is used as the test bed, and its layout is shown in Figure 1.

Vehicle detectors are installed in front of and in the vicinity of the junctions. They are shared between the two junctions. The connecting link between the two junctions can handle up 1800 vehicles in each direction per hour (i.e. saturation flow is 1800 vehicles per hour per lane). Due to varying driver and vehicle behavior some of the vehicles will be traveling faster and some slower because of which platoon dispersion can be observed on the link. Some of the vehicles might be park on the side of the road which acts as friction to the traffic flow. Also, we will consider a wide range of turning movement percentages.

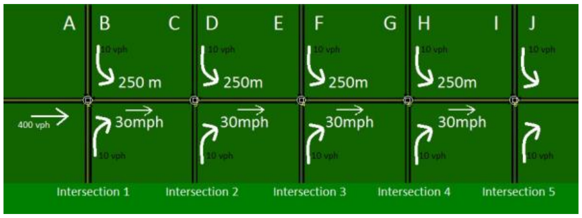

Figure 1. Five Junction Network

The network is first tested with constant traffic flow rates feeding the incoming roads of the network. The performance is compared with a network without favorable offset that attained by the network with offsets while they are coordinated. The offset is set at the average travel time between the two junctions, and the value of green time that is cycle time is kept unchanged, this would in general be a favorable case for that particular direction.

When signal phases are actuated, the cycle length and green times will vary from cycle to cycle in response to demand. To establish values for analysis, the operation of the signal should be observed in the field during the same period that volumes are observed. Average field-measured values of cycle length and green time may then be used.

IV. SIMULATION RESULTS

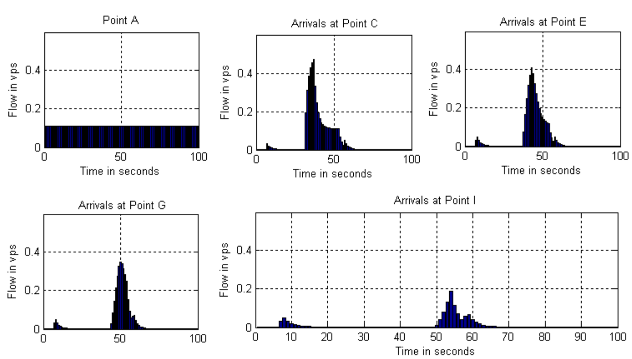

Figure 2. Arrival Flow Profile before offset

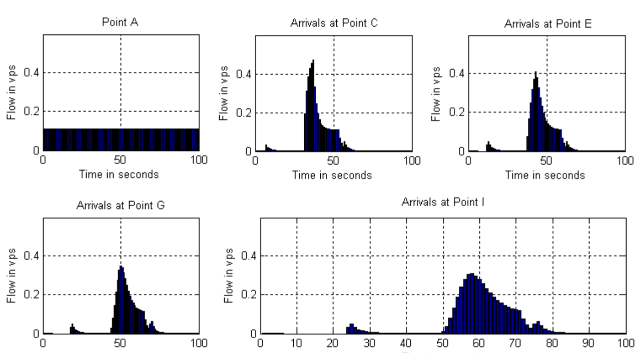

Figure 3. Arrival Flow Profile after Favourable Offset

In table we show an example how performance of a signalized arterial can be improved by using a favourable signal offset which help in reducing the delay of a link. Obviously, optimization of a delay will improve performance of network.

TABLE I

LINK	*Total Time*	*Total Time after offset*	*Delay Time*	*Delay Time after offset*	*Control Delay*	*Control Delay after offset*	*Queue Delay*	*Queue Delay after offset*	*Stop Time*	*Stop Time after offset*
(1, 2)	23.5	23.5	12.2	12.2	10.4	10.4	9.2	9.2	8.7	8.7
(2, 3)	21.3	14.5	10	3.2	7.3	1.3	6.9	1	6.8	1
(3, 4)	29.2	13.8	17.9	2.5	14.9	1.6	13.9	1.4	13.5	1.4
(4, 5)	22.3	13.7	11	2.4	8.2	1.5	7.7	1.2	7.6	1.2
(5, 6)	25.7	13.9	14.3	2.7	12.2	1.6	11.8	1.5	11.6	1.5
(6, 7)	12.6	11.5	1.2	0.5	0	0	0	0	0	0

V. CONCLUSION

This paper aims at optimizing signal timing which would lead to significant improvement in terms of the performance of road networks. For this purpose we have used a coordinated traffic control system. The optimization model using real-time data can give better results compared to the models using predicted data. Obviously it is worthwhile to implement PSO for a signalized arterial in an urban set up to improve its capacity and overall performance.

REFERENCES

[1] G. Improta and G. E. Cantarella, "Control systems design for an individual signalized junction," *Transp. Res., B*, vol. 18, no. 2, pp. 147–167, 1984.

[2] A. J. Al-Khalili, "Urban traffic control—A general approach," *IEEE Trans. Syst., Man, Cybern.*, vol. 15, no. 2, pp. 260–271, Mar. 1985.

[3] D. W. Ross, E. E. Humphrey, R. C. Mahoney, R. C. Sandys, G. L. Williams, R. Whonoutka, P. J. Wong, and H. M. Leidler, "Improved control logic for use with computer-controlled traffic," Stanford Research Inst., Stanford, CA, NCHRP Project 3-18(1) Rep., 1977.

[4] P. J. Tarnoff, "The results of FHWA urban traffic control research: An interim report," *Traffic Eng.*, vol. 45, no. 4, pp. 27–35, 1975.

[5] R. A. Vincent and C. P. Young, "Self-optimizing traffic signal control using microprocessor: The TRRL "MOVA" strategy for isolated intersections," *Traffic Eng. Control*, vol. 27, no. 7–8, pp. 385–387, 1986.

[6] D. I. Robertson and R. D. Bretherton, "Optimizing networks of traffic signals in real time—The SCOOT method," *IEEE Trans. Veh. Technol.*, vol. 40, no. 1, pp. 11–15, Feb. 1991.

[7] J. D. C. Little, M. D. Kelson, and N. H. Gartner, "MAXBAND: A program for setting signals on arteries and triangular network," in *Transportation Research Record 795*. Washington, DC: U.S. Dept. Transp., 1981.

[8] M. R. Crabtree, R. A. Vincent, and S. Harrison, "TRANSYT/10 user guide," in *TRL Application Guide 28*. Crowthorne, Berks., U.K.: Transp. Res. Lab., 1996.

[9] T. H. Heung, T. K. Ho, Y. F. Fung, Coordinated road-junction traffic control by dynamic programming, IEEE Trans. Intell. Transp. Syst., vol. 6, no. 3, pp. 341C350, Sep. 2005.

[10] C. R. Reeves, Genetic Algorithms: Principle and Perspective: A Guide to GA Theory. Boston, MA: Kluwer, 2003.

[11] M. D. Foy R. F. Benekohal, D. E. Goldberg, Signal Timing Determination Using Genetic Algorithms. In Transportation Research Record 1365, TRB. Washington, DC, 1992,pp.108-115

[12] M. A. Hadi, C. E. Wallace, Hybrid Genetic Algorithm To Optimize Signal Phasing and Timing. In Transportation Research Record 1421, TRB, Washington, DC,1993, pp.104-112

[13] G. Q. Memon, A. G. R. Bullen, Multivariate Optimization strategies for real time Traffic Control Signals. Presented at the 75th Annual Meeting of the Transportation Board, Washington, D. C., (1996)

[14] J. Kennedy and R. C. Eberhart. Swarm Intelligence. Morgan Kaufmann, UK, 2001.

[15] R.C. Eberhart and J. Kennedy A New Optimizer Using Particle Swarm Theory in proc. of sixth International Symposium On Micro Machine and Human Science (Nagoya, Japan) , IEEE Service Center 1995, pp 39-43.

[16] A Juan Chen Lihong Xu "Road-Junction Traffic Signal Timing Optimization by an adaptive Particle Swarm Algorithm", Control, Automation, Robotics and Vision, 2006. ICARCV '06. 9th International Conference.

[17] Chaojun Dong, Shiqing Huang, Xiankun Liu, "Urban Area Traffic Signal Timing Optimization Based on Sa-PSO," aici, vol. 3, pp.80-84, 2010 International Conference on Artificial Intelligence and Computational Intelligence, 2010.