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Application of genetic algorithms for joint optimization of signal setting parameters and dynamic traffic assignment for the real network data

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ABSTRACT

This paper presents the joint optimization of signal setting parameters and dynamic user equilibrium (DUE) traffic assignment for the congested urban road network. The simulation-based approach is employed to obtain the DUE condition for the case of multiple-origin multiple-destination traffic flows. The dynamic traffic assignment simulation program (DTASP), developed in C language is used to assign the traffic dynamically on the road network, whereas method of successive averages (MSA) is modified and used to arrive at the DUE condition. The artificial intelligence technique of genetic algorithms (GAs) is applied to obtain the optimal signal setting parameters and path flow distribution factor for DUE condition. The methodology developed in such a way that joint optimization of signal setting parameters with DUE is obtained. The proposed method is applied to the real network data of Fort Area of Mumbai city comprising of 17 nodes and 56 unidirectional links with 72 Origin–Destination pairs, where all the 17 nodes are signalized intersections. The traffic flow condition for the optimized signal setting parameters is considerably improved compared to the existing signal settings. The results prove that the GA is an effective technique to solve the joint optimization problem for the real network data.

1. Introduction

The performance of a traffic network can be influenced through several types of actions or decision variables. Some of these pertain to changing the load pattern on the network, through demand management actions, including attempts to route vehicles optimally through the network; others pertain to how traffic flow is controlled through signal control (supply management). Conventional methods for traffic signal optimization assume fixed traffic flows; whereas the traffic assignment methods assume fixed signal settings. This separation of traffic control from assignment may lead to inconsistency between traffic flows and signal settings because they are in general inter-dependent. The inter-dependence tends to be more serious in congested networks. The inconsistency may be eliminated by combining signal optimization with an equilibrium assignment. The combined signal optimization and user equilibrium (UE) traffic assignment problem is one in which a traffic engineer tries to optimize the performance of signals while road users choose their routes in a UE manner (Maher & Zhang, 1999).

Some of the most important theoretical contributions to the problem of signal control and UE static assignment are made by Smith (1979, 1981), who derived conditions that guarantee the existence of an equilibrium as well as conditions for the uniqueness and stability of the traffic equilibrium when there is interaction between signal setting and users' route choice decisions. Allsop (1974) has proposed an iterative solution procedure for the UE static assignment problem in a pretimed signal-controlled network. Charlesworth (1977) obtained mutually consistent traffic assignment and signal settings through an iterative procedure in which the TRANSYT software is used to optimize the signal settings. In dynamic traffic assignment (DTA) models, a trip may be regarded as a combination of departure time and route choice; consequently departure rates and hence flows and travel times are time dependent. Ghali and Smith (1993) have implemented an iterative procedure using CONTRAM and showed the convergence pattern for DTA. Gartner and Stamatiadis (1997) have presented a general conceptual framework for the implementation of a combined solution for DTA and signal control, but they have not

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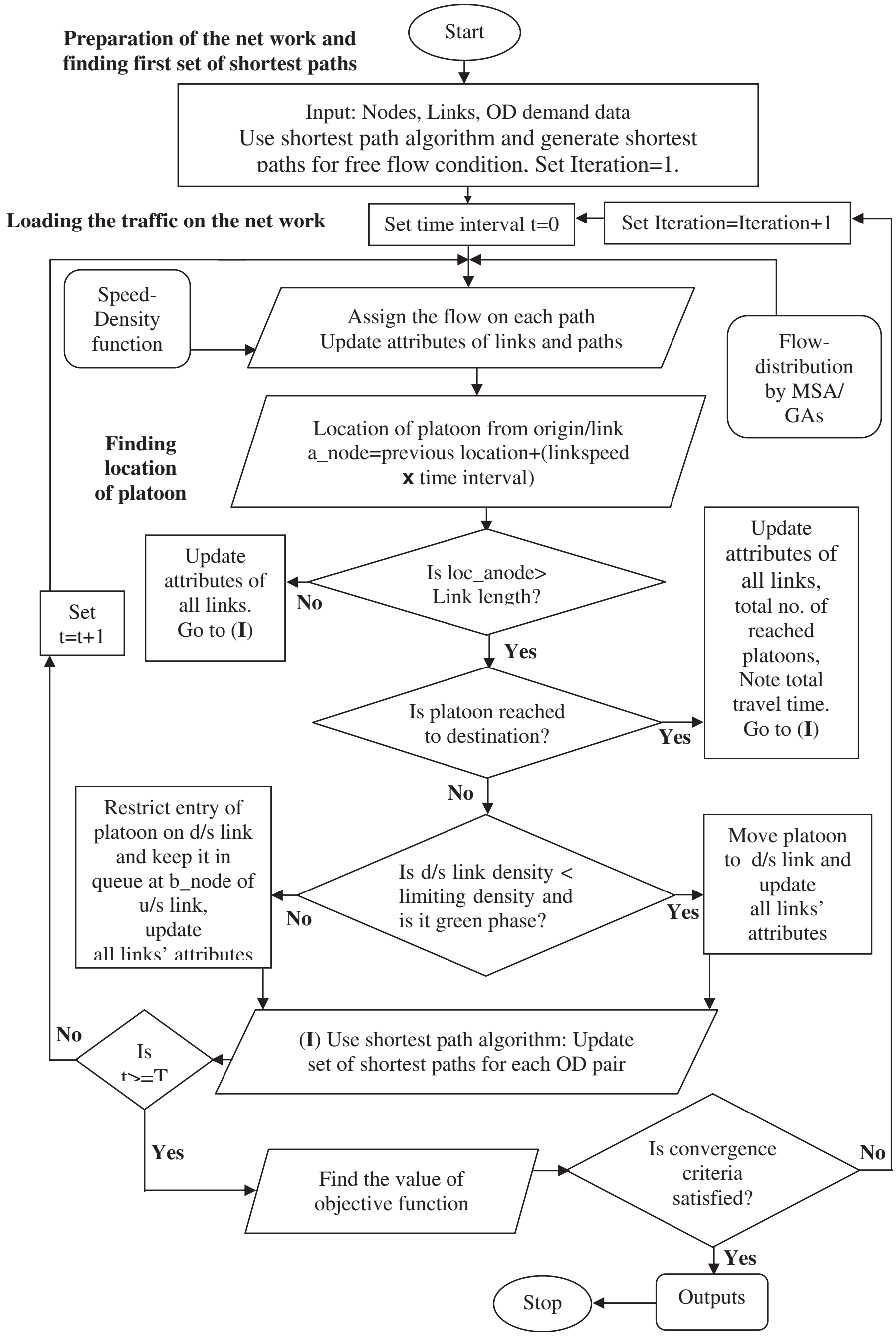

Fig. 1. Flow chart of simulation program DTASP.

reported implementation of a specific algorithmic procedure. Abdelfatah and Mahmassani (1998: pp. 185–193) have presented a formulation and solution algorithm for the combined system optimal DTA and signal control. Abdelghany, Valdes, Abdelfatah, and Mahmassani (1999) have introduced and illustrated the path-based signal coordination as an example of integrating signal control with network traffic assignment using the real-time DTA.

Signal optimization and DUE condition can be carried out as a joint optimization problem or as a bi-level programming problem. The DUE is based on Wardrop's first principle: "no driver can unilaterally reduce his/her travel costs by shifting to another route" (Wardrop, 1952). In the joint optimization problem, decision variables for signal optimization are cycle time, green splits and phase sequence, whereas appropriate path flow distribution is a decision variable for the DUE problem. Both the problems are solved simultaneously. It is easier to identify the convergence to the optimal solution. Whereas, in the bi-level programming problem, signal optimization is the upper-level problem and DUE assignment is the lower-level problem. As the DUE assignment procedure is iterative, bi-level programming approach requires longer time and also it is difficult to identify whether the iterations are converging to the optimal solution. The associated objectives may not always act in tandem. Moreover, looking to the necessity of solving DTA problem for on-line deployment with faster computational tractability, joint optimization approach is more preferable to adopt compared to the bi-level programming. Considering this, in this