Transportation Research Part C 66 (2016) 48–60

Contents lists available at ScienceDirect

Transportation Research Part C

journal homepage: www.elsevier.com/locate/trc

Bee Colony Optimization for innovative travel time estimation, based on a mesoscopic traffic assignment model

Mauro Dell'Orco [a,*], Mario Marinelli [a], Mehmet Ali Silgu [b]

[a] D.I.C.A.T.E.Ch., Technical University of Bari, Via Orabona 4, 70125 Bari, Italy
[b] Institute of Science and Technology, Technical University of Istanbul, Ayazaga Campus, Maslak, 34469 Istanbul, Turkey

ARTICLE INFO

Article history:
Received 31 January 2015
Received in revised form 22 September 2015
Accepted 1 October 2015
Available online 21 October 2015

Keywords:
Traffic flow
Travel time
Mesoscopic simulation
Bee Colony Optimization

ABSTRACT

In this article, we propose a framework for travel time prediction based on a time-discrete, mesoscopic traffic flow model, in which the measure of travel time is obtained as a link performance resulting from a dynamic network loading process. The spatiotemporal flow propagation on the road network is simulated incorporating the mesoscopic model and a linear link performance model, based on a travel time function. Acceleration levels are calculated explicitly, as a result of a fixed point problem. The traffic assignment to the network has been carried out through a completely new model, based on the Bee Colony Optimization (BCO) metaheuristics. In comparison with results of simulations carried out by using another mesoscopic model (DYNASMART), the travel times obtained with the proposed method appear more realistic.

1. Introduction

The interaction among transportation systems and land use characteristics, in the absence of appropriate planning strategies, creates an increasing traffic demand, which strives more and more the transport infrastructure, and causes chronic congestions. Such congestions result in an increase of generalized traveling costs, and in particular of travel time.

In recent years, travel time has become a focal point in many studies within the frame of both transportation planning and traffic engineering. The travel time measure keeps being not only an important criterion for the performance evaluation of transportation systems but also a major component for advanced innovative information systems. Accurate estimation and prediction of travel times and real-time traffic information are important factors that directly affect the viability of dynamic traffic systems' implementations. Thus, an adequate procedure for travel time estimation can be useful in avoiding inherent difficulties of real-time measurements on travel times. On one hand, a reasonable amount of large-scale studies on network-wide spatiotemporal traffic flow characteristics has been conducted considering explicitly travel times. On the other hand, at relatively smaller scales the specification of link-path flow characteristics is still an essential research topic. However, determining travel times in a correct and realistic, and thus reliable, manner is a common point in both cases.

In this work, we present a novel DTA-based travel time estimation model that lies its basis on a mesoscopic dynamic network loading, firstly presented by Dell'Orco (2006).

Representation of anisotropic traffic flow properties is a general problem in mesoscopic models; in our model, as time step reduces, the influence of vehicles that gradually enter a link on vehicles in front decreases, but cannot be ruled out entirely. For this reason, the proposed model is not completely anisotropic, but quasi-anisotropic.

* Corresponding author. Tel.: +39 0805963327; fax: +39 0805963329.
E-mail address: mauro.dellorco@poliba.it (M. Dell'Orco).

http://dx.doi.org/10.1016/j.trc.2015.10.001

We have used the Sioux-Falls City road network to perform a dynamic network loading process by simulating the spatial and temporal flow propagation. Then, we have analyzed the performances of our model in reconstructing travel times on a road network through a completely new traffic assignment model, based on the Bee Colony Optimization (BCO) metaheuristics. In addition, we carried out a comparative evaluation, considering average speed and travel time obtained both by our model and by a popular commercial software.

In the following, we have first examined a variety of studies concerning fundamentally the travel time estimation/reconstruction, and then we have considered the most common mesoscopic models. Afterwards, the performance of our model in a reliable reconstruction of travel times is then compared to that obtained using DYNASMART. Finally, we conclude the paper with an evaluation of findings and future solution directions on the topic of interest.

2. Travel time estimation: a short literature review

2.1. Link travel time estimation

In mathematical analyses of transportation problems, an extensive variety of practical and theoretical studies taking into account travel time as a performance measure. Mainly, there are two approaches for performing travel time estimation: direct estimation by measurement, or indirect estimation.

2.1.1. Direct estimation of travel time by measurement

A measure of travel time can be derived in several ways by utilizing various types of traffic data collection systems. For example, you can track vehicles equipped with a cellular phone in terms of their cell location (Astarita and Florian, 2001; Pathirana et al., 2006). However, the accuracy of this method is heavily influenced by the size of the cellular phone network cell and the transmission quality (Pathirana et al., 2006).

Other approaches include automatic vehicle identification (AVI) (Turner et al., 1998), license plate recognition (Anagnostopoulos et al., 2006), tag reading and Bluetooth (Haghani et al., 2010).

Alternatively, probe vehicles equipped with a global positioning system (GPS) module and a transmission interface can transmit information regarding their spatial position and speed to a service center (Brockfeld et al., 2007). Methods for performing travel time estimation using GPS and GIS technologies have been proposed in addition to studies that explicitly consider the collection scheme of traffic data (Turner et al., 1998). In this study, to evaluate the performance of the flow model, we have assumed that travel time measurements obtained by a GPS equipped probe vehicle are actual travel times.

2.1.2. Indirect estimation of travel time

Indirect methods of travel time estimation can be subdivided into two main categories: trajectory based and traffic flow model based.

Trajectory methods are conceived to be the simplest and most widely accepted methods for the estimation of travel time from traffic sensor/detector data (Cortes et al., 2001). The trajectory methods proceed with the assumption that the point estimates of speed are representative of the average speed between contiguous detection points.

Nagel and Schreckenberg (1992) introduce a stochastic discrete automata model to freeway traffic. Through Monte-Carlo simulations, the model shows that, with increasing vehicle density, a shift from a laminar traffic flow to start-and-stop waves occurs, like in real freeway traffic.

Van Lint and Van der Zijpp (2003) propose an algorithm for the off-line estimation of route-level travel times for uninterrupted traffic flow facilities, based on an improved trajectory method; afterwards, Van Lint (2004) proposes and analyzes some different models and methods. Still Van Lint et al. (2005) proposes a framework for prediction of freeway travel time, both accurate and robust with respect to missing or corrupt input data, to be applied in a real-time environment.

Wang et al. (2014) based their citywide, real-time model for estimating the travel time of any path on the GPS trajectories of vehicles received in current time slots and over a period of history as well as map data sources.

Several authors, like Hoogendoorn (2000), Coifman (2002), and Oh et al. (2003), just to mention a few, have presented traffic flow theory-based models, ensuring initial and boundary conditions as well as the flow conservation principle.

However, some of the models perform well solely in case of free or almost free flow patterns (Hoogendoorn, 2000; Oh et al., 2003), while some other models are only applicable for congested flow patterns (Nam and Drew, 1998).

Treiber and Helbing (2002) proposed a robust adaptive smoothing method for the spatiotemporal approximation of flow patterns, which takes into account the characteristic propagation speeds observed in both uncongested and congested conditions.

Corthout et al. (2012) focused on the problem of possible non-uniqueness of the solution of Dynamic Network Loading (DNL) models and provided approaches on how one can deal with.

Bekhor et al. (2013) presented a system for the collection and analysis of free-flow travel speeds on a road network, mainly focusing on the road safety and possible counter-measures employed to reduce excessive speeds.