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Better convergence for dynamic traffic assignment methods

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Abstract

An essential feature in many of the dynamic traffic assignment methods that are used to study planning and traffic management problems is to compute the dynamic user equilibrium (DUE). In this paper the focus is on efficiently computing the deterministic and stochastic DUE. Both these types of equilibria are found using an iterative solution procedure. An important step in the solution algorithm for deterministic assignments is the choice for the contraction factor which determines how fast the related quadratic programming problem is solved. For stochastic assignments the step size to determine the starting point for the next iteration is important for convergence speed. As we show, the contraction factor and the step size heavily affect both the convergence efficiency and stability. We discuss various fixed contraction factors, a number of step size adjustments proposed by others, and a newly proposed dynamically adjusted step size. The solution method is evaluated on two transport networks of different scale. The comparative analysis suggests that, particularly for larger networks where equilibrium is harder to obtain, a dynamic adjusted contraction factor for deterministic assignments or a dynamic step size for stochastic assignments is preferable as it consistently converges considerably faster, because it does not suffer from a decreasing convergence rate.

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1. Introduction

In traffic and transport models are used for several applications, for example to underpin policy choices, to determine the impact of infrastructural or traffic management measures, to make a better planning for road works and the accompanying measures, to test traffic systems, to train traffic operators, to support decisions that are made by the traffic operators, to optimise traffic management plans or to aid evaluation studies. For all these applications different traffic models are available with their own characteristics, input demands and pitfalls. For planning purposes and to calculate the effect of policy measures most of the time traffic assignment models are used.

Traffic assignment models are concerned with the distribution of the demand among the available routes for every origin-destination pair and if it is a dynamic traffic assignment model also for every time period. Starting with the original four-step transport models, traffic assignment models have evolved into useful tools for traffic research, also

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in a dynamic context. The dynamic part is important, because traffic is a dynamic process. Travel demand changes during the time of day and has a large influence on traffic operations and this has to be captured by this type of models.

There is a large amount of literature concerning the development and application of traffic assignment models. For an overview of the relevant literature, the reader is referred to Chen (1999) and Bliemer (2001). According to the classification of Chen (1999) a deterministic dynamic user optimal assignment, a stochastic dynamic user optimal assignment and a system optimum assignment can be distinguished. In the paper the focus will be on deterministic and stochastic dynamic traffic assignment. Both these types of assignment use an iterative procedure to get to an equilibrium solution. An important step in the solution algorithms is the choice of the step size to determine the starting point for the next iteration. The paper will discuss the current practise in choosing these step sizes and previous reported improvements (Pel et al., 2010) and will also suggest other methods to improve convergence. The results in terms of the solution (equilibrium flows and travel times) and the time needed to reach that solution will be given for a number of networks.

First we will summarise some literature on the topic and then describe some characteristics of the dynamic traffic assignment models we use and we then will focus on the convergence properties of the deterministic and stochastic assignment methods.

2. Literature

Dynamic traffic assignment models focus on predicting time-varying network conditions by describing route choice behaviour of drivers on an infrastructure network and the way in which the traffic dynamically flows over the network. A common assumption within traffic assignment models is referred to as user equilibrium, first formalized by Beckmann et al. (1956), and pertains to the route flow assignment under which drivers travel times are unilaterally minimised. Here an important distinction can be made between the deterministic equilibrium where drivers act homogeneously and the stochastic equilibrium where heterogeneity in drivers route choice behavior is accounted for. The latter leads to the well-known Logit and Probit models first proposed by Dial (1971) and Daganzo and Sheffi (1977) where unobserved influence factors are assumed to be respectively Gumbel and Normal distributed among drivers.

The equilibrium assignment relates to a fixed-point problem, as route choices and travel times are interdependent, and can be solved by an iterative process. Over consecutive iterations, [1] the route traffic flows are loaded onto the network to yield travel times, [2] convergence is checked to know whether equilibrium conditions are (sufficiently) satisfied, and if not, then [3] route flows are redistributed, typically based on the route flows and travel times found in the previous iteration or iterations. Decisions made in each of these modelling steps may influence the equilibrium assignment.

For the network-loading step, a model is used to simulate the traffic flows. Examples of commonly used simulation-based models are various queuing models (Mounce, 2006), the Cell Transmission Model (Ziliaskopoulos and Lee, 1996) and the Link Transmission Model (Gentile, 2015), and second order Kinematic Wave-based models such as METANET (Messmer, 2000). As this is beyond the scope of this paper, we refer the interested reader to Mahmassani and Alibabai (2010) who discuss how the traffic flow phenomena captured by these various network-loading models affect the existence of equilibrium and the convergence of solution algorithms.

In checking for convergence, usually one uses an equilibrium gap function to measure how close drivers travel times are to equilibrium, such as the duality gap. Or otherwise a proxy indicator is sometimes used that measures how the consecutive intermediate solutions in the iterative process stabilize, such as marginal changes in route flows or travel times between iterations. Mounce and Carey (2011) discuss these various convergence measures. Evidently, an equilibrium gap function can guarantee convergence, while the mere stabilisation of intermediate solutions may not necessarily guarantee convergence depending on the flow redistribution method that is used (see also Chiu et al. (2011)).

In this paper we are particularly interested in how traffic flows are redistributed across routes. The reason is that the iterative convergence procedure tends to be computation time-consuming, while the latter flow redistribution step largely determines the efficiency and efficacy of the iterative process in finding the equilibrium assignment. Here indeed efficiency i.e., computation time or number of iterations as well as memory usage and efficacy i.e., convergence accuracy are the dominant criteria when comparing and evaluating different flow redistribution methods.