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Solving large-scale urban transportation problems by combining the use of multiple traffic simulation models

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Abstract

Transportation agencies often resort to the use of traffic simulation models to evaluate the impacts of changes in network design or network operations. They often have multiple traffic simulation tools that cover the network area where changes are to be made. Nonetheless, these multiple simulators may differ in their modeling assumptions (e.g., macroscopic versus microscopic), in their reliability (e.g., quality of their calibration) as well as in their modeling scale (e.g., city-scale model versus regional-scale model). The choice of which simulation model to rely on, let alone of how to combine their use, is intricate. A larger-scale model may, for instance, capture more accurately the local-global interactions; yet may do so at a greater computational cost. This paper proposes a methodology that enables the simultaneous use of multiple traffic simulation models.

We propose a simulation-based optimization algorithm that embeds information from simulation models with different levels of accuracy and with different levels of computational efficiency. The algorithm combines the use of high-accuracy low-efficiency models with low-accuracy high-efficiency models. This combination leads to an algorithm that can identify points with good performance at a reduced computational cost.

We evaluate the performance of the algorithm with a traffic signal control problem on a small network. We show that the proposed algorithm identifies signal plans with excellent performance, i.e., with reduced average trip travel times, while doing so with a reduction in the computational cost.

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1. Introduction

Consider a subnetwork within a larger network (e.g., an arterial within a city, a city within a region) where local changes to the supply of the subnetwork are being considered. Transportation agencies often resort to the use of traffic simulators in order to determine the changes to be carried out (e.g., changes in the network design or in the traffic control), and to evaluate the impacts of these changes both locally (i.e., within the subnetwork) as well as globally (i.e. at the larger-scale).

Transportation agencies often have multiple simulators that cover the subnetwork of interest. Nonetheless, these multiple simulators may differ in their modeling assumptions (e.g., one model may be macroscopic, another microscopic), in their reliability (e.g., quality of their calibration) as well as in their modeling scale (e.g., one may be a city-scale model, another a regional model). Most often, transportation experts will consider the advantages and disadvantages of each model, and will ultimately choose one model to rely on in order to determine and study in detail the subnetwork changes. The choice of a model is not an easy task. A larger-scale model may, for instance, capture more accurately the local-global interactions; yet may do so at a greater computational cost.

In this paper, we propose a simulation-based optimization (SO) framework that allows for the combined use of multiple simulation models. We assume that we have access to two models that cover the subnetwork of interest and both have the same modeling assumptions (e.g., same behavioral models). Let R denote the larger scale simulation model (R stands for regional), and C denote the smaller scale simulation model (C stands for city). We assume that the subnetwork of interest where network changes are to be carried out is the full network of C . This subnetwork is entirely modeled in R . This is a scenario which one can easily encounter in practice, where R is an available large-scale model, and C is a smaller model extracted from R , and calibrated based on R outputs. The model R is assumed to lead to more accurate estimates of both local and global performance; yet is significantly more expensive to evaluate.

The family of transportation problems that we consider is continuous and generally constrained problems. The objective function is estimated via a stochastic simulator, whereas the constraints are available in closed-form and are differentiable. Such a problem can be formulated as follows.

$$\min_x \quad f(x) = E[F(x; \tilde{p})] \quad (1)$$

$$\text{subject to} \quad h(x; \tilde{p}) = 0 \quad (2)$$

$$x \in \mathbb{R}^n. \quad (3)$$

In this formulation x represents the decision vector. F is the random variable that describes network performance (e.g., trip travel time). In this formulation the objective function is the expected value of F . The objective function is an unknown function. We can only obtain estimates of it via stochastic simulation. The simulation model is also a function of exogenous parameters (e.g., network topology, calibrated behavioral models) which are represented by $\tilde{p}$. The constraints represented by the function h are available in closed-form. For instance, in the signal control problem considered in this paper they represent green time constraints for every intersection (e.g., bounds, linear constraints).

In this paper, we assume that the objective function accounts for the local (i.e., subnetwork) performance. That is, the aim is to improve local conditions. We propose a simulation-based optimization (SO) technique that allows for simultaneous use of both simulators, R and C , in order to address such a problem. The goal is to achieve a suitable trade-off between obtaining accurate local performance estimates and the associated computational costs.

Recent reviews of traffic simulation models include Barceló (2010), Ratrout and Rahman (2009). The main families of models are known as macroscopic, mesoscopic and microscopic. Microscopic simulation (also referred to as microsimulation) models are the most detailed, yet also the most computationally inefficient models. Their computational inefficiency limits their use to address large-scale transportation problems. On the other hand, macroscopic models are computationally more efficient and hence are often used for the analysis of large-scale

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