Integrating Iterative Backpropagation (IB) and Metamodeling for High Dimensional Dynamic Traffic Model Optimization

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Abstract

Transportation modeling has been experiencing constructive transformation towards a new generation of multimodal and dynamic models capable of microscopic simulation of peoples' activities, individual vehicles, and network topologies. MATSim being one of such models has been becoming popular in recent days. Due to its procedural solution algorithm and modular, agent-based structure, MATSim enjoys superiority in modeling capability over traditional methods. However, the procedural steps and modularity result in high computational cost and a lack of closed-form solution and gradient information.

Application of any of such models often requires optimization in the form of calibration. Moreover, even though these models can support policy and decision support systems in the form of different scenario analysis, they are most beneficial when the underlying model is optimizable for high-dimensional control variables. MATSim, due to its lack of closed-form solution and gradient information, is hardly optimizable and has been mostly used for scenario analysis for different policy decisions in the past. Recently, some hybrid response surface has been developed in the literature for optimization of MATSim and similar costly to evaluate traffic models, where the response surface employs a simplified traffic model. A polynomial function is then used to bridge the gap between the two models (Osorio, 2019; Patwary et al., 2021). However, even the simplified traffic models can become costly to evaluate for a large-scale, multimodal network. In addition, due to the iterative solution algorithm of most traffic assignment models, the hybrid response surface lacks closed-form gradient information. Given numerical gradient estimation techniques require as many function evaluations as the dimension of the problem, high dimensional optimization of MATSim and similar traffic models becomes a challenging problem to solve.

The Iterative Backpropagation (IB) algorithm was recently developed for high dimensional, gradient-based static TA optimization (Patwary & Lo, 2017). This algorithm backpropagates the equilibrium output gradients through the iterations of the traffic model solution algorithms to generate the high-dimensional gradients of the traffic assignment outputs at equilibrium. In this research, we plan to implement IB algorithm and hybrid metamodeling for large-scale dynamic traffic assignment model, specifically MATSim optimization.

Unlike the original metamodel simulation-based optimization (SBO) framework by Osorio & Bierlaire (2013), we implement a gradient-based optimization framework based on the popular learning algorithm ADAM (Kingma & Ba, 2015). In addition to the metamodel fitting step, the metamodel IB SBO algorithm implements a gradient correction step within the metamodel optimization. The fitting step fits a generic polynomial that bridges the gap between the original simulator and the simplified traffic model. The gradient correction step adjusts the IB gradient of the simplified traffic model using the gradient of the fitted polynomial. The combined gradients are then used in each iteration of the metamodel optimization. The metamodel IB SBO algorithm is illustrated in Figure 1.

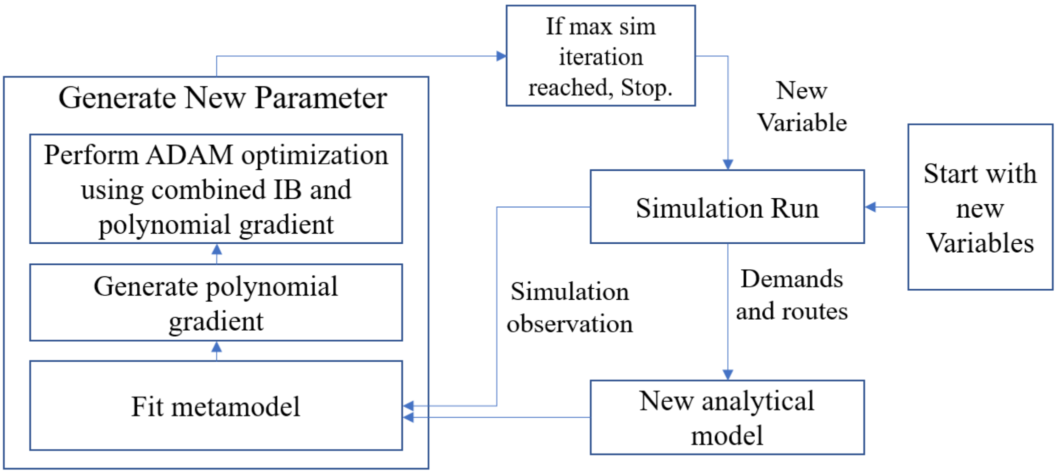

Figure 1: Metamodel IB SBO algorithm

The proposed method is applied for high dimensional OD optimization for Hong Kong multimodal network. Preliminary results show that the framework is capable of providing improved solutions over the initial objective. The algorithm opens up ways for high-dimensional optimization problems for large-scale traffic simulators, specially MATSim.

Keywords: Metamodeling, Simulation-based optimization, Iterative Backpropagation, OD estimation, MATSim

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