Joint Calibration for DTA Model Using Islands-GA and PC-SPSA

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Abstract

Dynamic Traffic Assignment (DTA) models are widely used in transportation system management. Calibration is a crucial step to improve the reliability and the accuracy of DTA models. We present a systematic framework to offline calibrate the supply and demand component of a DTA model. The essence of model calibration is an optimization problem, aiming to minimize the discrepancy between field conditions and simulated traffic measurements. To overcome limitations of a single optimization algorithm, a joint approach is developed for the calibration of supply and demand component respectively with different traffic measurements. As the calibration process is a nonlinear and stochastic problem, heuristic algorithms: the Genetic Algorithm (GA) and the Simultaneous Perturbation Stochastic Approximation (SPSA) Algorithm, are implemented as a complement solution. Instead of using the standard GA, to expedite searching efficiency, we introduce the Islands Genetic Algorithm (IGA) and SPSA with Principal Component Analysis (PC-SPSA) to solve the calibration problem. A case study on a network of Munich, Germany, is used to validate the proposed methodology. The promising results indicate that calibration of the supply and demand component of a DTA model with the proposed joint approach improves modelling accuracy. In comparison, IGA outperforms standard GA in terms of convergence speed and solution quality.

Keywords: Dynamic Traffic Assignment; Islands Genetic Algorithm; PC-SPSA

1. Introduction

Dynamic Traffic Assignment (DTA) models are widely employed to estimate and predict traffic state dynamically. The basic structure of a DTA model consists of a supply component and a demand component. A supply component represents network characteristics and simulates individual driving behaviors. A demand component includes Origin-Destination (OD) flows. Therefore, calibration for both supply and demand component is an essential step to improve reliability of DTA models.

The motivation of this research is to provide a systematic framework for offline DTA model calibration and to give corresponding solution techniques (Antoniou et al., 2007, 2016). The essence of model calibration is an optimization problem, aiming to minimize the discrepancy between observed field conditions and simulated traffic measurements. To overcome limitations of a single optimization algorithm, a joint approach is proposed for the calibration of supply and demand component respectively with different traffic measurements. Considering the complex nature of DTA model, the calibration is performed with link speeds for supply component and OD flows for demand component. This research contributes to the literature by implementing the Islands Genetic Algorithm (IGA) and the Simultaneous Perturbation Stochastic Approximation with Principal Component Analysis (PC-SPSA) as solution algorithms for the supply and demand component respectively. The scalability of PC-SPSA has been validated in previous studies (Qurashi et al., 2019). However, the application of IGA in DTA model calibration is very sparse in the literature of DTA calibration. The IGA has advantages to overcome some typical issues that often occur in optimization process such as premature convergence and local optimal solution and improves computational efficiency. In this research, we compare IGA and GA with the same configuration and evaluate the robustness of IGA. The standard GA (Ma and

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Abdulhai, 2002) is treated as a benchmark in terms of convergence speed and solution quality. A case study on a network of Munich, Germany, is used to demonstrate the proposed methodology.

2. Methodology

We propose a systematic framework for offline DTA model calibration. A mesoscopic simulator is used to represent the DTA model that consists of a supply and a demand component. We use archived traffic data to represent historical traffic patterns. A multi-objective function is formulated to evaluate the calibration results (discrepancy between simulation outputs and historical traffic data). Different traffic measurements are used for the supply and demand component. We follow an iterative calibration process: calibration of supply parameters with fixed demand parameters and recalibration of demand parameters with constant (calibrated values from previous step) supply parameters. The essence of DTA model calibration boils down to an optimization problem. It is a Non-deterministic Polynomial-time Hardness (NP-hard) problem. Therefore, a heuristic algorithm, Islands-GA, is employed to calibrate supply side parameters, whereas, PC-SPSA algorithm is used to calibrate the demand side parameters.

3. Case study

We conduct our case study on a network of Munich, Germany. A metropolitan urban network of Munich consists of a dense city center, surrounding arterials, and a highway bypass. There are 2408 links (about 946 km in length) and 1475 nodes in the network model. For the traffic analysis purpose, the network is divided into 61 traffic analysis zones, generating an OD matrix with 3721 OD pairs. The SUMO (http://dlr.de/ts/sumo) serves as our mesoscopic simulator for generating simulated traffic measurements. The calibration results show that the joint approach of Islands-GA and PC-SPSA is an effective tool for DTA model calibration.

4. Conclusion

A systematic framework for offline DTA model calibration is proposed. Considering that the nature of model calibration is a NP-hard problem, the framework concatenates two heuristic algorithms, IGA and PC-SPSA, to iteratively calibrate the supply and demand component respectively with different traffic measurements.

A case study on a network of Munich is used to validate the proposed methodology. We calibrate the link speeds with traffic counts for the supply component and calibrate OD flows with OD travel time for the demand component. The calibration results indicate that IGA and PC-SPSA significantly improve model accuracy. In addition, IGA outperforms standard GA with the same configuration. Thanks to the existence of the isolated islands, IGA maintains genetic diversity and therefore evolves much faster than the standard GA. With the enlarged search space, IGA overcomes the problem of trapping in local dilemma that often occurs to the standard GA, thus providing nearly global optimum solution. Further research is required to extend the offline calibration framework to online context.

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References


