International Journal of Transportation Science and Technology 6 (2017) 63–77

Contents lists available at ScienceDirect

International Journal of Transportation Science and Technology

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

Calibration of microscopic traffic simulation models using metaheuristic algorithms

Miao Yu, Wei (David) Fan *

Center for Advanced Multimodal Mobility Solutions and Education, Department of Civil and Environmental Engineering, University of North Carolina at Charlotte, 9201 University City Blvd., Charlotte, NC 28223, USA

ARTICLE INFO

Article history:
Received 6 April 2017
Received in revised form 16 May 2017
Accepted 20 May 2017
Available online 25 May 2017

Keywords:
Calibration
Microscopic traffic simulation model
Genetic algorithm
Tabu Search
Warm start

ABSTRACT

This paper presents several metaheuristic algorithms to calibrate a microscopic traffic simulation model. The genetic algorithm (GA), Tabu Search (TS), and a combination of the GA and TS (i.e., warmed GA and warmed TS) are implemented and compared. A set of traffic data collected from the I-5 Freeway, Los Angles, California, is used. Objective functions are defined to minimize the difference between simulated and field traffic data which are built based on the flow and speed. Several car-following parameters in VISSIM, which can significantly affect the simulation outputs, are selected to calibrate. A better match to the field measurements is reached with the GA, TS, and warmed GA and TS when comparing with that only using the default parameters in VISSIM. Overall, TS performs very well and can be used to calibrate parameters. Combining metaheuristic algorithms clearly performs better and therefore is highly recommended for calibrating microscopic traffic simulation models.

Introduction

Due to the cost effectiveness, risk free, and high speed benefits (Ciuffo et al., 2008), microscopic traffic simulation has been widely used in transportation planning, design, and analysis. In recent years, the microscopic approach has also been given more importance in traffic operations and safety studies. Many microscopic simulation models (such as VISSIM, CORSIM, and SUMO) have been widely used. In these simulation models, there are independent parameters that are used to describe traffic flow characteristics (e.g. driver behavior and traffic control operations). Even though these microscopic simulation models provide default values for these parameters, simulation under default values often produces unreliable results. Users often have to fine-tune the values so that traffic conditions of real case studies can be accurately represented. Therefore, the parameters of microscopic simulation models need to be calibrated and validated. Model calibration plays a crucial role in minimizing the differences between the simulation results and corresponding field measurements, such as traffic volumes, speed, and travel time.

To obtain a close match between the observed and simulated traffic measurements, one has to perform a proper calibration of microscopic traffic simulation model parameters. Because there are a large number of unknown parameters involved, the calibration process can be a time-consuming and complex task. As a result, such calibration process has been formulated

Peer review under responsibility of Tongji University and Tongji University Press.
* Corresponding author.
E-mail addresses: myu6@uncc.edu (M. Yu), wfan7@uncc.edu (W. (David) Fan).

http://dx.doi.org/10.1016/j.ijtst.2017.05.001
2046-0430/

as an optimization model in which a huge search space exists due to a wide range of each relevant model parameters. The optimal set of parameters is solved and obtained so that the objective function can be minimized (Ciuffo et al., 2008; Cheu et al., 1998; Paz et al., 2012, 2015; Balakrishna et al., 2007; Toledo et al., 2004; Jha et al., 2004; Ma et al., 2007; Kim et al., 2005; Ma and Abdulhai, 2002; Park and Qi, 2005; Lee and Ozbay, 2009; Hourdakis et al., 2003; Chiappone et al., 2016; Menneni et al., 2008; Abdalhaq and Baker, 2014; Hale et al., 2015). However, such optimization process typically does not have gradient information to assist the search for an optimum solution (Ma et al., 2007; Hourdakis et al., 2003). Researchers cannot directly apply mathematical programming methods, and therefore metaheuristic methods (such as the genetic algorithm (GA)), simultaneous perturbation stochastic approximation (SPSA), or trial-and-error method (IA), are used to search for optimal parameter values.

Among these algorithms, GA has been widely used due to its easy implementation and good performance in calibration and optimization (Ma et al., 2007; Kim et al., 2005; Ma and Abdulhai, 2002; Park and Qi, 2005; Chiappone et al., 2016; Menneni et al., 2008; Abdalhaq and Baker, 2014; Paz et al., 2015; Fan and Gurmu, 2014; Fan and Machemehl, 2006, 2004). However, other algorithms, such as Tabu Search (TS) method, may also provide an effective solution to the calibration problem. TS has been widely applied in many fields since it was first proposed by Glover in 1977 (Glover, 1986). It has been successfully used to obtain optimal or sub-optimal solutions to problems, such as the traveling sales person, timetabling and layout optimization, and transit route network optimization (Fan and Machemehl, 2008).

To the best of current knowledge, the authors of this study have noticed that the TS has rarely been used for the calibration of microscopic simulation model parameters. Furthermore, all these research efforts have used one algorithm to calibrate the microscopic simulation models. However, it is believed that the warm start method (using the solutions obtained from one algorithm as a starting point for another algorithm) will have superior performance compared to using a single algorithm alone (Fan et al., 2008). As such, this study attempts to use TS to calibrate the parameters of the microscopic traffic simulation model (i.e. VISSIM) with a real world freeway case. At the same time, GA works as a baseline comparison because GA can obtain an acceptable calibration result which has been proven by many researchers (Cheu et al., 1988; Ma et al., 2007; Kim et al., 2005). Perhaps the most significant contribution of this paper is to introduce the warm start concepts and use the warm start methods for the first time for calibration. In particular, GA, TS, and a combination of the GA and TS (including both warmed GA and warmed TS methods) are implemented to calibrate the microscopic traffic simulation models. Particular attention is given to the algorithm comparisons and warm start component. To implement this process, the existing GA tool in MATLAB is used and new TS tools algorithms are developed and implemented in MATLAB for calibration. The optimization techniques are used and attached to VISSIM 7.0 via component object model (COM) interface so that the data can transfer between MATLAB and VISSIM. The calibration results of GA, TS, warmed GA, and warmed TS methods are then evaluated, compared and discussed.

The rest of this paper is organized as follows: Literature review presents a summary of literature on the calibrations of traffic simulation models. Calibration methods discusses the calibration methods in which the objective function is given first and the GA and TS methods are then introduced. The VISSIM calibration parameters are also described. Real world case study provides the case study. In Calibration results, simulation and calibration results are discussed in detail. Finally, conclusions are made and future research directions are also given in Conclusion.

Literature review

A reliable calibration process must include: the definition of a criterion to evaluate the performance of a model in terms of an objective function, parameters that will be calibrated and optimized, and the algorithm that will be developed to optimize the calibration process and minimize the objective function (Dowling et al., 2014). In Table 1, the case study, objective function and optimization algorithm(s) used in each study during the calibration process are summarized and presented.

Parameters

There is substantial variation in the number of parameters (from 2 to 15) being calibrated among these case studies, however, most of such parameters seem to be only related to driver behavior. For example, Ciuffo et al. only calibrated driver's reaction times and speed acceptance (Ciuffo et al., 2008). In Cheu et al.'s research, the mainline free-flow speeds upstream and downstream of North Buena Vista Road off-ramp and the free-flow speeds at on-ramps and off-ramps, as well as the parameters that control the movement of vehicles (e.g., minimum car-following distance and sensitivity factor) were calibrated, and a total of 12 parameters were calibrated in their research (Cheu et al., 1998). In Paz et al.'s study, 11 parameters for freeways and 15 parameters for surface streets were calibrated (Paz et al., 2015). Generally speaking, a small number of parameters enables the researchers to pay more attention to each parameter when its value is changed. However, some other parameters may have little impact on the performance individually, but could have significant impact when combined. As such, the optimal parameter set obtained may only be a local optimal calibration solution. On the other hand, with more parameters, the calibration solution can be closer to an optimal one although the solution space can be huge and the time it takes to find the optimal parameter set can also be much longer. Based on such tradeoff considerations, an appropriate set of calibration parameters should be selected based on the sensitivity analysis results conducted by modifying relevant VISSIM