JOURNAL OF TRAFFIC AND TRANSPORTATION ENGINEERING (ENGLISH EDITION) 2017; X (X): 1–16

Available online at www.sciencedirect.com

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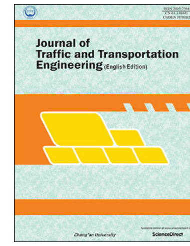
journal homepage: www.elsevier.com/locate/jtte



Original Research Paper

VISCAL: Heuristic algorithm based application tool to calibrate microscopic simulation parameters

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HIGHLIGHTS

- An automated VISSIM calibration tool, VISCAL, is developed supporting three heuristic optimization algorithms.
- VISCAL can test the significance of the appropriate decision parameter set for a particular network.
- VISCAL can determine the most suitable objective function to reflect network characteristics.
- VISCAL can check the suitability of any of the three heuristic optimization algorithms for a particular network.
- Combination of multi-objective criteria and GA provides the best estimation for speed and flow in the freeway scenario.

ARTICLE INFO

Article history:
Received 10 October 2016
Received in revised form
6 April 2017
Accepted 7 April 2017
Available online xxx

Keywords:
VISSIM
Genetic algorithm
Simulated annealing
Simultaneous perturbation
stochastic approximation

ABSTRACT

VISCAL (VISSIM calibration) is an automated calibration tool for microscopic simulation parameters in VISSIM environment, based on three heuristic optimization algorithms: (a) genetic algorithm (GA); (b) simultaneous perturbation stochastic approximation (SPSA); (c) simulated annealing (SA). It is developed with a goal to automate and ease the tedious process of calibration, offering greater flexibility to the users by providing control on every aspect of the calibration process. It includes multiple features for a generic application tool with the ability to test the significance of the appropriate decision parameter set for a particular network, to determine the most suitable objective function to reflect network characteristics, and to check the suitability of any of the three heuristic optimization algorithms for a particular network. VISCAL also offers four objective function choices into the system: (1) speed, (2) flow, (3) delay, and (4) multi-objective criteria. It is able to calibrate all the driving behavior parameters for any type (urban, rural) and extent of network (small or large network). However, for this study, the operation of the tool is tested by a dataset obtained from a 3.26 km freeway of Dhaka, Bangladesh.

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Peer review under responsibility of Periodical Offices of Chang'an University.
https://doi.org/10.1016/j.jtte.2017.04.004

1. Introduction

Microscopic traffic simulation tools (e.g., VISSIM, PARAMICS, MITSIM, AIMSUM, etc.) have gained popularity due to extensive features that enable network design and evaluation, planning and analysis, etc. These features include flexible representation of spatial and temporal demand patterns, modeling of complex interaction between vehicles and driving behavior, replicating driving decisions (e.g., route choice), and simulating operations of traffic management strategies. However, the developed micro-simulation model is a complex constitution of several components based on a large number of inputs and parameters to best represent observed local traffic conditions. Therefore, model calibration that ensures the accurate reflection of the local driving environment by matching model output with measured field values is a crucial step in building a reliable microscopic traffic simulation model.

Complexity of the calibration problem calls for an adequate optimization technique that can produce an optimal parameter set, saving both time and effort. Researchers widely used heuristic methods due to its ability to continuously adapt search in response to intermediate trial results. For example, genetic algorithm (Essa and Sayed, 2015; Kim et al., 2005; Ma et al., 2007; Ma and Abdulhai, 2002; Park and Qi, 2005), simulated annealing (Park and Yun, 2006), simultaneous perturbation stochastic approximation (SPSA) (Balakrishna et al., 2007; Paz et al., 2014)and complex algorithm (Toledo et al., 2004)have been used in different studies. These algorithms automated the calibration process to a certain degree and generally improved the simulation performance over default model parameter values for the particular study area. Many of the projects and research studies have investigated and proposed new techniques for the calibration process. However, to the authors' best knowledge very few has furnished a general application tool, offering flexibility and practicality for any real-world calibration problem, such as GENOSIM (Ma and Abdulhai, 2002), VISGAOST (Stevanovic et al., 2007). This is may be due to the complex interrelationship among the large number of micro-model parameters, cost associated with the single or multi-criteria objective function replicating actual network characteristics, and underlying differences of the algorithm parameters of different optimization techniques.

Calibration of a micro-simulation model is a time-consuming task and even a medium sized network can take months to be built, spending most of the time on calibrating the parameters. This is because much of the accuracy or satisfactory outcome of the simulation model is dependent on the appropriate selection of parameters. Most of the calibration studies focused on specific parameter set, such as, driving behavior parameters (Balakrishna et al., 2007; Kim et al., 2005; Toledo et al., 2004), mean target headway and mean reaction time (Gardes et al., 2002; Lee et al., 2001), car following factors (Kim and Rilett, 2003; Schultz and Rilett, 2004), O–D flow (Toledo et al., 2004; Jha et al., 2004) and etc. Others identified the significant parameters that have a definite effect on the driving behavior and performance of the network and then calibrated those parameters (Dowling et al., 2004; Hourdakis et al., 2003; Kim and Rilett, 2003; Ma and Abdulhai, 2002; Park and Qi, 2006). Thus, choice of parameters decision for a particular micro-model either appropriate or inappropriate will has positive or negative impact on the network performance as measured by a relevant objective function. This process of appropriate parameter selection when automated will definitely provide a time-effective solution to the user.

Objective function plays a critical role in expressing the network characteristics and adds to the complexity of the calibration process. Mostly objective function is based on either single criterion (speed, flow, or delay) or, multi-objective criteria (speed–flow, density–flow, etc.). However, it should be noted that each single evaluation of the objective function is very costly, depending on the scale (small or large) of the built network, and the number of simulated vehicles. From practical cost consideration, calibration process in most of the studies was based on single criteria objective function (e.g. speed, or flow). Based on these criteria, some studies showed good performances using speed (Toledo et al., 2004), some showed satisfactory result using flow (Kim et al., 2005; Kim and Rilett, 2003; Ma and Abdulhai, 2002). Very few studies have worked with multi-objective criteria (e.g., speed–flow) (Paz et al., 2015). The limitation of using single criteria objective function is that the minimization of error based on only one criterion does not necessarily reflect likewise for other objective functions. All these studies represent one particular and important fact that the objective function is data-specific and network-specific. This implies that a particular objective function suitable for a particular study network may not bring representative outcome for another network. Thus, it is a primary concern to underscore the suitable objective function for a particular network emphasizing on the single or multi-objective criteria, otherwise the entire calibration process will generate unrealistic outcome. Due practical considerations, an opportunity to select the best suitable objective function for a particular network through an automated process would greatly reduce the cost and increase the efficiency of the calibration process.

For heuristic algorithms, the underlying parameters of different algorithms are significantly different from the others. These algorithms start with a feasible parameters' set(s) and evaluate the closeness between the field measurements and simulation under the feasible set(s). Every algorithm possesses unique rules that are used to replace the unfit parameter sets by better ones iteratively until the gap is narrowed to a satisfactory level. For instance, genetic algorithm (GA) is a stochastic search method based on the principles and mechanisms of natural selection and survival of the fittest from natural evolution whereas the simultaneous perturbation stochastic approximation (SPSA) method preforms the search operation along the gradient approximation at every iteration. The operation of the simulated annealing (SA) is also significantly different from other algorithms, where SA escapes local optima by allowing hill-climbing moves (i.e., moves that worsen the objective function value). These differences make it difficult to decide on a generic optimization algorithm for the calibration process. For instance, a satisfactory outcome obtained from using GA for a particular network does not ensure that likewise outcome will be