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Calibration of traffic flow models using a memetic algorithm

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ABSTRACT

A Memetic Algorithm (MA) for the calibration of microscopic traffic flow simulation models is proposed in this study. The proposed MA includes a combination of genetic and simulated annealing algorithms. The genetic algorithm performs the exploration of the search space and identifies a zone where a possible global solution could be located. After this zone has been found, the simulated annealing algorithm refines the search and locates an optimal set of parameters within that zone. The design and implementation of this methodology seeks to enable the generalized calibration of microscopic traffic flow models. Two different Corridor Simulation (CORSIM) vehicular traffic systems were calibrated for this study. All parameters after the calibration were within reasonable boundaries. The calibration methodology was developed independently of the characteristics of the traffic flow models. Hence, it is easily used for the calibration of any other model. The proposed methodology has the capability to calibrate all model parameters, considering multiple performance measures and time periods simultaneously. A comparison between the proposed MA and the Simultaneous Perturbation Stochastic Approximation (SPSA) algorithm was provided; results were similar between the two. However, the effort required to fine-tune the MA was considerably smaller when compared to the SPSA. The running time of the MA-based calibration was larger when it was compared to the SPSA running time. The MA still required some knowledge of the model in order to set adequate optimization parameters. The perturbation of the parameters during the mutation process must have been large enough to create a measurable change in the objective function, but not too large to avoid noisy measurements.

1. Introduction

The calibration of traffic flow simulation models continues to be an open area of research. Various frameworks have been proposed in literature to address the associated optimization problem (Coello et al., 2012), but not general enough to provide adequate results for the large number of available simulation models and required traffic scenarios. Fig. 1 illustrates the general conceptual calibration process, where model inputs are adjusted between realistic boundaries until simulation results are reasonably close to field measurements (Eckhardt et al., 2005). That is, the optimization problem searches for the values

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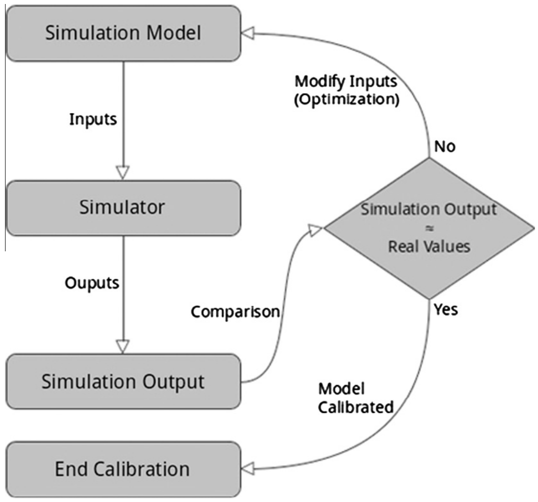

Fig. 1. Conceptual calibration process.

required by the parameters of the simulation model to minimize the difference between simulation outputs and the corresponding field measurements.

The solution space for the optimization is defined by the range of model parameters. A broad number of algorithms have been proposed to solve the optimization problem for a particular traffic flow system and/or simulation model (Hollander and Liu, 2008). One such algorithm proposed was the evolutionary approach, which uses genetic algorithms (Omrani and Kattan, 2013; Cunha et al., 2009). Genetic algorithms have been used for the calibration of micro-simulation models for the distribution of commercial vehicles (Schultz and Rilett, 2005). Other researchers have claimed that metaheuristics could provide superior results (Merz and Freisleben, 1999).

The sequential simplex algorithm was used to calibrate parameters for such as car-following, acceleration/deceleration, and lane-changing behavior (Kim and Rilett, 2003); however, only a subset of parameters was considered. The required computational time was considerably high and the solution could be a local optima. Stochastic approximation methodologies were used for the simultaneous calibration of traffic flow model parameters (Park et al., 2009; Park and Kamarajugadda, 2007; Chien, 1982). The SPSA (Spall, 1998) has been widely used for the calibration of various traffic flow models. When compared to Genetic algorithms and Iterative Adjustment algorithms, the SPSA has shown similar accuracy to the other algorithms, but with less computational time (Ma et al., 2012). This algorithm has been used to calibrate driver behavior and vehicle performance parameters simultaneously, with the use of such traffic measurements as vehicle counts (Balakrishna et al., 2007).

Although these methodologies could provide adequate results, a complex process to fine-tune algorithmic parameters was required for each model (Yuan et al., 2013; Paz et al., 2012). The research community has produced a large number of approaches for the calibration of simulation-based traffic flow models, a single automated methodology capable of calibrating various simulation models and traffic scenarios, which is not yet available in the literature. The primary challenge was the lack of a generalized optimizer algorithm for calibration of traffic flow models. This has motivated the development of MA, which combined global and local research mechanisms. That is, MA combined an extensive search of the best zones on the search space (exploration) and a more detailed search was performed on the zones with superior possible solutions (exploitation). The equilibrium between exploration and exploitation improved the results (Neri et al., 2012). Hence, MA was excellent for problems involving large search space.

Depending on the mechanisms chosen for a global and local search, a MA could be implemented and used easily, with little need for fine-tuning of the model parameters. For practical purposes a MA could provide improved results, more than other well established approaches such as Genetic Algorithms, Tabu Search, and Simulated Annealing (Garg, 2009).

In this study, a MA was proposed to search for the values of the parameters used by the traffic flow simulation model, to minimize the difference between simulation and the corresponding field measurements. Previous studies have either considered a subset of model parameters, a single performance measure, or fine-tuning was required for the parameters used by the optimization algorithm. The proposed methodology implements a MA to determine an adequate set of all model parameters. To the best of knowledge, the authors of this study have noticed that MAs have not been used for the calibration of traffic flow models. The proposed algorithm seeks to minimize user intervention during the calibration process. The parameters used by the proposed MA were relatively simple to fine-tune and were independent of the characteristics of the traffic flow simulation model (Weyland and Hagen, 2008; Pellerin et al., 2004). During the experiments, various simulation models and scenarios were calibrated with a MA, using the same values for its parameters. Optimization algorithms in the existing literature involve an extensive sensitivity analysis of the algorithm parameters. In addition, most methodologies require pre-calibrated model parameters and/or demand patterns to achieve adequate results (Wang et al., 2012; White and Chaubey, 2005).