Towards data-driven microscopic traffic simulation models

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Extended abstract

Traffic simulation models have been used for several decades to conduct detailed analysis of traffic networks. Traffic simulation models play an important role in traffic management and safety research. Modeling traffic behavior has also contributed significantly in the development of Intelligent Transportation Systems (Koutsopoulos and Farah, 2012). Zhang et al. (2011) have expressed the need for a shift from a conventional technology-driven system into a more powerful multifunctional data-driven intelligent transportation system. Microscopic models describe driving behavior and interactions among vehicles. Moving towards autonomous driving, more and more reliable and accurate models are required. Nowadays, there has been an increasing interest in self-driving or autonomous vehicles. Aiming at safety, reliability and convenience, an autonomous vehicle should adapt to user preferences and simulate human driving reactions naturally, preventing abrupt acceleration and jerk (Kuderer et al., 2015). Nowadays, technological advances have significantly improved our traffic data collection capabilities and increasing volumes of potentially useful data are readily available in low-cost opportunistic sensors. As a result of an explosive increase of the data that are being generated and collected, data-driven modeling is emerging as a fast developing field of transportation research.

At a macroscopic level, Antoniou and Koutsopoulos (2006) have proposed estimation of traffic dynamics models using machine learning approaches instead of the classic way of speed-density relationships. In the context of mesoscopic traffic simulation models, Antoniou et al. (2013) have developed a methodology based on data-driven models for the identification and short-term prediction of traffic state and local speed. The results are promising and the introduction of data-driven models into microscopic traffic simulation needs to be also investigated.

In this research an integrated methodological framework based on non-parametric approaches is proposed for estimation of data-driven microscopic traffic simulation models. The objective of this research is to develop more accurate, robust and reliable microscopic models. The methodology is demonstrated using real trajectory data from three different sources and specifically an experiment from Naples (Punzo et al., 2005), NGSIM data and non-lane disciplinary trajectory data from India (Kanagaraj et al., 2015). Two different approaches of data-driven models are proposed.

The first methodological approach includes a practical and simple approach for the online calibration of microscopic traffic simulation models, which considers dynamic parameters for individual drivers, in time and space. The model learns from data and adapts to driving behavior in a rolling horizon and leads to less than 10% error in speed prediction even for ten steps into the future, in all considered datasets (Figure 1).

The second methodological approach aims to increase model flexibility and provide the opportunity for incorporation of additional parameters without the need to resort to cumbersome reformulations of traditional models functional form. The methodology is implemented using different computational approaches such as locally weighted regression (Loess), multivariate adaptive regression splines (MARS), Gaussian processes (GP), Kernel support vector machines (KSVM) and Bayesian regularized neural networks (BRNN). These methods are effectively employed with clustering and classification techniques, so as more detailed models to be produced. The focus is given on car-following models and Gipps' model, one of the most extensively used car-following models, is calibrated against the same data in order to be used as a reference benchmark. The performance of all the models presented in this research is evaluated using several goodness-of-fit measures so as a comprehensive and objective assessment of prognostics performance to be provided. In addition, a policy evaluation methodology based on distributions rather than single aggregate measures is applied, too. Then, a comparison among the different models is presented and comparative benefits as well as limitations of each one are identified. Flexible models outperform the reference traditional model for all available data series (Figure 2).

Many parameters affect driving behavior and in this research it is explored how the performance of the models is improved by including more parameters. Machine learning techniques that allow the incorporation of additional information, such as traffic density, vehicle type of both the leader and following vehicles, may lead to more detailed models, and are very difficult to integrate within conventional, analytical models. The effects of different predictor variables on the models are explored through a quantitative and qualitative analysis. For a more in depth analysis, a meta-model is developed to evaluate the magnitude of the effect of the considered predictor variables on the models.

After the validation of data-driven models on data of vehicles characterized by lane discipline, this research examines the feasibility and the benefits of using data-driven models on mixed traffic trajectory data, which are characterized by non-lane discipline and heterogeneity in vehicle types, common characteristics of cities in the developing world.

Typical car following models are relied on mathematical formulas and are theoretically justified, though they are more restrictive. On the other hand, machine learning approaches may not provide as much insight into traffic flow theory as the traditional models do, though they are more flexible and allow the easy incorporation of additional information to the process of speed estimation. The results indicate that computational approaches could ensure reliability and improvement in estimation of microscopic models. Finally, data-driven models could provide a robust solution to autonomous driving and be incorporated in traffic microsimulators.

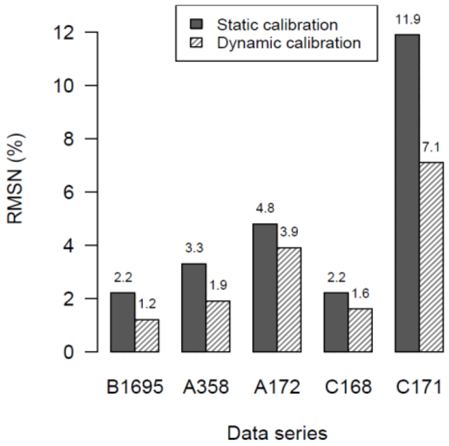

Figure 1: Normalized mean square error of speed estimation for Naples data (first methodological approach)

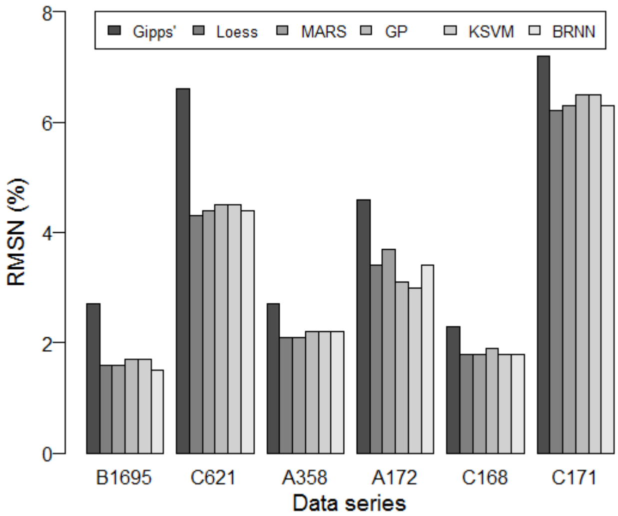

Figure 2: Normalized mean square error of speed estimation for Naples data (second methodological approach)

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