A Generative Modeling Framework for Network-Wide Traffic State Estimation: A Macroscopic Fundamental Diagram Approach

Master‘s Thesis of Amin Alimohammadi

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Introduction

The problem of traffic state estimation in the urban context is valued for transportation management systems (TMSs). Meanwhile, high spatiotemporal correlations could be observed throughout the dynamic system of urban traffic. Therefore, the notion of Macroscopic Fundamental Diagram (MFD) is used in this study to estimate the key variables of traffic flow. More precisely, the main objective of this work is to propose a generative modeling framework which incorporates the concept of MFD and aims to impute missing traffic data.

Methodology

The data of 255 loop detectors embedded near 30 intersections in the city of Darmstadt is used to estimate the network-wide MFD for one weekday in July 2021. Since almost all of the loop detectors in Darmstadt are located very close to traffic signals, the MFD estimation is highly prone to bias. To mitigate this bias, a method is adopted from literature. In the meantime, using the same dataset, traffic speed is estimated for single road segments, which are then rescaled utilizing floating car data (FCD). The distributions of speed values are then studied to propose a Gaussian mixture model which consists of an optimum number of components. Finally, a random sample of size N is generated from the mixture model in each 5-minute time interval. Each sample represents the speed values on N road segments without loop detectors.

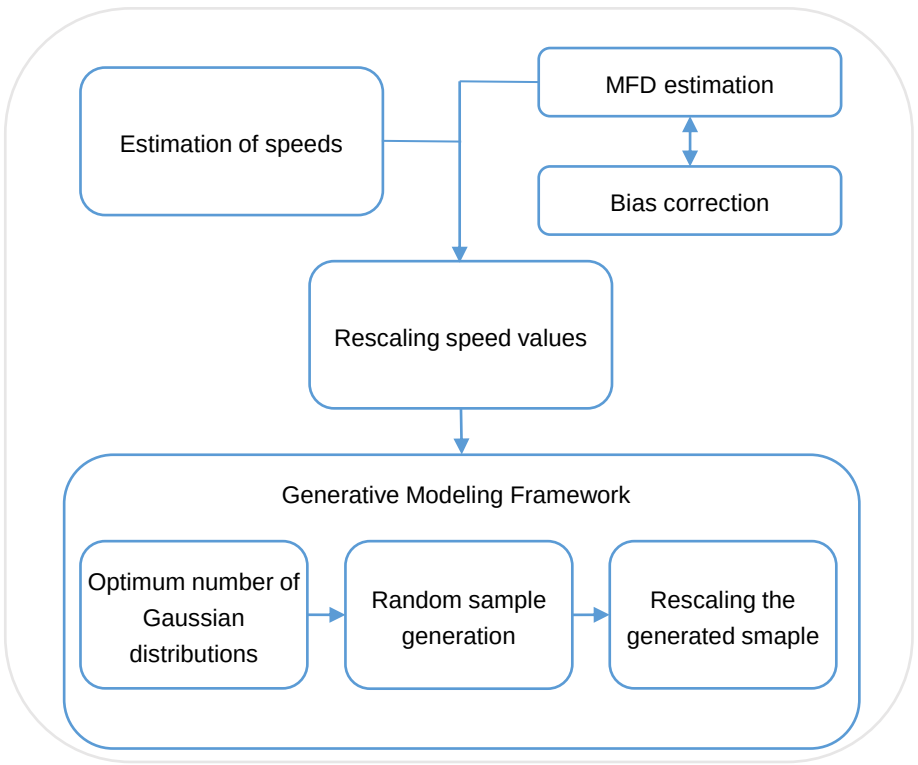

Figure 1. Workflow of Methodology

Results

The results of each step of this study is presented in the following figures. Firstly, the estimated MFD is depicted. Secondly, the process of fitting a Gaussian mixture model to the distribution of speeds is illustrated. Finally, the generated sample of speeds both before and after rescaling is compared to the speeds retrieved from FCD.

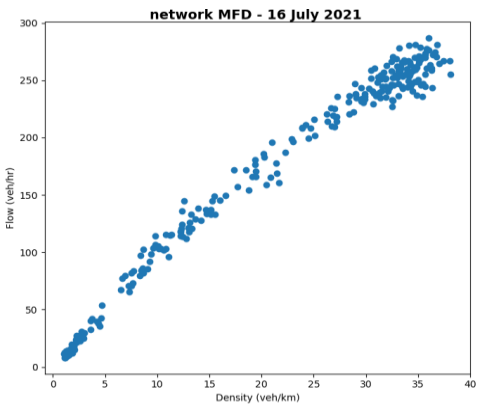

Figure 2. Network-wide MFD

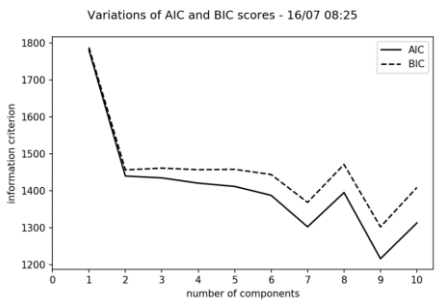

Figure 3. AIC and BIC scores

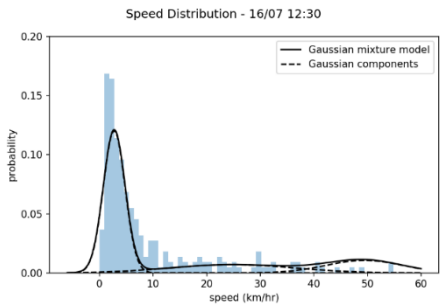

Figure 4. 3-component GMM

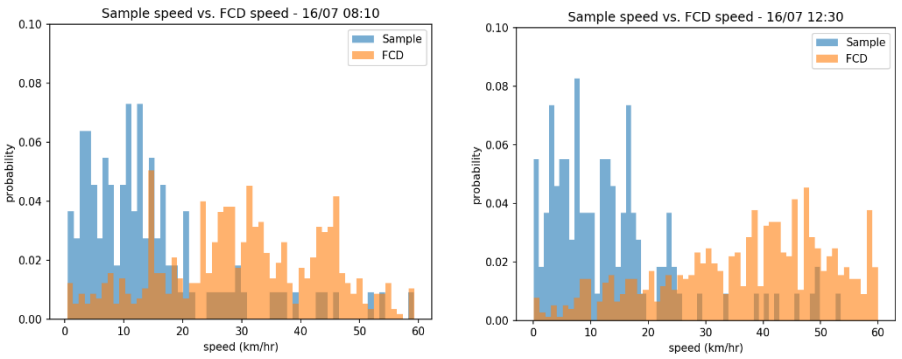

Figure 5. Generated sample speed vs. FCD speed

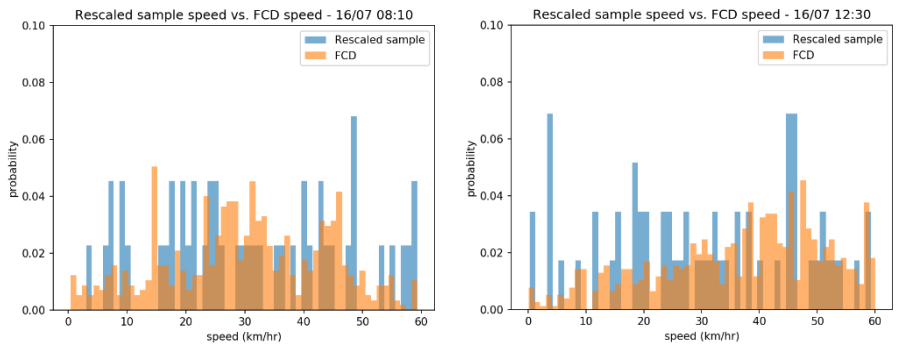

Figure 6. Rescaled generated sample speed vs. FCD speed

References

Ralf Tank. Verkehrsdaten Darmstadt. Verkehrsdaten im Rohformat. https://datenplattform.darmstadt.de/verkehr/apps/opendata/#/

Ambühl, L., et al. 2018. Introducing a re-sampling methodology for the estimation of empirical macroscopic fundamental diagrams. Transportation Research Record 2672, 20, 239-248.