Linking the microscopic traffic flow mechanics with the macroscopic phenomena by exploiting class-type traffic information retrieved from online traffic maps

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Abstract

The conversion from single-entity level characteristics of traffic flow to comparable system-level characteristics shaped a new era for traffic monitoring and control. Since then landmark studies explored network-level traffic flow relationships across entire urban networks or regions and cities, mainly based on simulation data but also with empirical data. Although, the ability to observe and monitor the traffic state of the system on a network-wide level depends on the availability of existing traffic surveillance systems, adequately deployed such as to cover a complete network. To overcome this deficit, we propose a method to estimate a network's Macroscopic Fundamental Diagrams (MFD) using traffic flow mechanics at the microscopic level and exploiting class-type traffic information that can be obtained from online traffic maps. This valuable information depicted on maps is extracted based on image processing techniques, able to simultaneously perform discretization of the urban space and the road network therein in seamless pixels and further capture the color-coded traffic information in a suitable data structure valuable for meta-analysis. Then, the fundamental traffic flow mechanics are used for connecting the captured pixels properties with macroscopic traffic phenomena, especially with the well-defined (MFDs). The validity of the method is tested by comparing the estimated MFDs to ground-truth MFD obtained using empirical data from loop detectors. The results are providing valuable evidence on the operational characteristics of large urban areas, while at a meta-analysis stage it was able to capture spatio-temporal phenomena of urban mobility, like concentration, hysteresis and homogeneity. Since online traffic maps provide almost global coverage the proposed method is practically feasible and offers a novel approach for monitoring large-scale traffic systems.

Keywords: Online Traffic Maps; Empirical Data; Image Processing; Macroscopic Fundamental Diagram.

1. Introduction

Given the MFD of a network, effective traffic management and monitoring strategies can be readily developed to treat congestion phenomena. However, the data needed to estimate the MFD are not always readily available. Through a literature review, most of the existing research has concentrated on the estimation of the MFD based on empirical data such as Loop Detector Data (LDD) or Floating Car Data (FCD). The position of the loop detectors in the network along with the network coverage and the spatial distribution influence the shape of the MFD while the probe penetration rate in the case of FCD is an important issue for further consideration. In the light of other data sources

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Peer-review under responsibility of the scientific committee of the 23rd EURO Working Group on Transportation Meeting.
limitation, the capturing of macroscopic phenomena utilizing online traffic maps’ information presents great value (Gkania and Dimitriou, 2019).

2. Method and Data

To explore the capacity of online traffic maps for estimating network-wide phenomena (e.g. in the detail that MFDs are offering), fundamental traffic variables were first estimated utilizing measurements from the whole network. For achieving that, a connection between the average network flow, the average network speed, the average network density, and the number of pixels that belong to distinctive operating class of online traffic maps was established. Then in order to estimate the average network density, a parametric approach was followed based on the fundamental linear speed-density relation proposed by Greenshields (Greenshields, 1935). To evaluate the proposed method, snapshots of online traffic maps from the City of Nicosia, Cyprus, were collected, covering one week (11-17 February 2019). As can be seen in Fig. 1, four different colors are used for distinguishing the traffic state for the whole road network (Green, Orange, Red and Dark Red). After a preliminary data preprocessing and filtering procedure, 1806 consecutive online traffic map images were collected using 5-minute interval. Then, an extraction procedure of the color layers was applied to the dataset, organized in seamless pixels’ 3D matrices. Prior the application of the proposed method that enables the estimation of MFDs for the City of Nicosia (Fig.1), an empirical calibration of the models was employed, utilizing available loop-detector data for the same network. Traffic data were also collected for the same week, from four available loop detectors, numbered 1004, 1005, 1006, 1010, located mainly in bidirectional cross-sections of major arteries in Nicosia (Fig. 1). The observations of the loop detectors were used to calibrate the proposed models through a standard optimization process, aiming to minimize the error between observed traffic and estimated from the traffic maps.

Fig. 1. (a, b) Nicosia’s MFDs for the selected week; (c) The location of the loop detectors in Nicosia, Cyprus

3. Results and Concluding Remarks

In this paper we proposed for the first time in the literature, a method to estimate a network’s MFD using data, extracted from online traffic maps. Following a back-engineering approach, traffic layers are captured by straightforward image processing techniques and processed as a categorical type of data, for meta-analysis. Then, fundamental traffic relationships are used, connecting microscopic information to macroscopic phenomena. The results indicate that the fundamental macroscopic properties still hold even in cases of significant information reduction like the representation scheme adopted in online traffic maps. Not only the shapes and the magnitude of scale among the traffic variables are consistent with field observations, but also valuable additional information can be extracted from traffic maps (like vehicles concentration, network heterogeneity, etc.) and delicate phenomena can be captured (like traffic hysteresis).

References
