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Using mobile phone data for urban network state estimation

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The ubiquity of mobile phones is producing ever-increasing amounts of data, providing invaluable information that can be used to study many aspects of our everyday life. A promising way of exploiting this data is the modelling of mobility patterns, such as the use of mobile network data, as a complementary source for estimating dynamic road traffic conditions. A major motivation for estimating urban mobility from mobile data is that transportation sensing infrastructure is costly in terms of installation and maintenance, has limited coverage and is intrusive. In a mobile network, all participants generate data, i.e. stationary and mobile users alike. From a transportation perspective, mobile network data can then be referred to as *exogenic* data, as the data encompasses not just the transportation network agents but the entire mobility of individuals.

In our research we explore how mobile data can be used for various estimation and modelling tasks in transportation. Essentially, by looking at mobile networks as distributed traffic sensors, we want to show that they can serve as a complement to the existing, traditional transportation data sources. In particular, in this study, we want to explore ways of estimating supply-related metrics in a cost-neutral and privacy-friendly way. To do so, we introduce a methodology for estimating vehicular density and flows in analogy to the concept of Macroscopic Fundamental Diagram [1], using mobile network handovers as input data. In the presentation we will show that the presented supply model works both in simulated- and real-data settings, and compare the results from both worlds. The supply models developed from mobile data enable the optimization of traffic by controlling the flows between zones, e.g. via gating [2]. Past research in this direction has focused mainly on highways and on using mobile phone data at a regional scale (e.g. [3]). The main study in urban traffic areas was done by Calabrese et al. [4], who performed analyses of the Telecom Italia dataset for the city of Rome. Our study targets urban mobility patterns and is complementary to [4] as we focus on network states rather than on the demand side.

We want to establish a model in the form of $v = q * k$, i.e. the fundamental flow-density relationship for partitions of the road network, in analogy to the concept of MFDs. Since in mobile networks the phone's precise serving cell is only known during an active data or call connection, we cannot access the density of mobile phones directly (as the majority of them typically are in a passive, disconnected state). Thus, we propose a three-stage approach:

1. First, we partition the road network in areas that are large enough to capture the traffic dynamics of MFDs;
2. Next, we model each partition's density using handovers within and from the partition;
3. Finally, we use linear regression to estimate the traffic state from exiting flows and approximated density, thus optimizing the regression coefficients for all time intervals and partitions.

For each partition, we propose a density modeling function based on the ratio between the scaled internal and exiting flows. We propose to express this relationship using a polynomial with interaction, where the degrees and coefficients are the parameters characteristic of each partition. Details on the model formulation are given in the presentation and in the full paper.

The dataset used in this study is composed of two elements. The first is the position of LTE base stations and the corresponding cell identifiers hosted on this base station. The second is the number of handovers

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between any given cell pair per hour. We test the state estimation model using simulated data coming from mobile phones, while we simulate synthetic floating car data for validation purposes. The simulation scenario we base our study on is the LuST scenario by Codeca et al. [5] for the microscopic traffic simulator SUMO [6]. Floating car data is also used as ground truth in the real data analysis, where the mobile dataset used is the LTE network data from the largest mobile operator in Luxembourg, Post.

Figure 1. Partitioning of Luxembourg City network

Figure 1 shows the partitioning we use both in the simulation and real-data studies. We opted for 4 partitions, representing the main geographical zones of Luxembourg City, i.e. physically separated plateaus. Note, however, that road network partitioning can also be done algorithmically and depending on the flows, e.g. using spectral clustering [7].

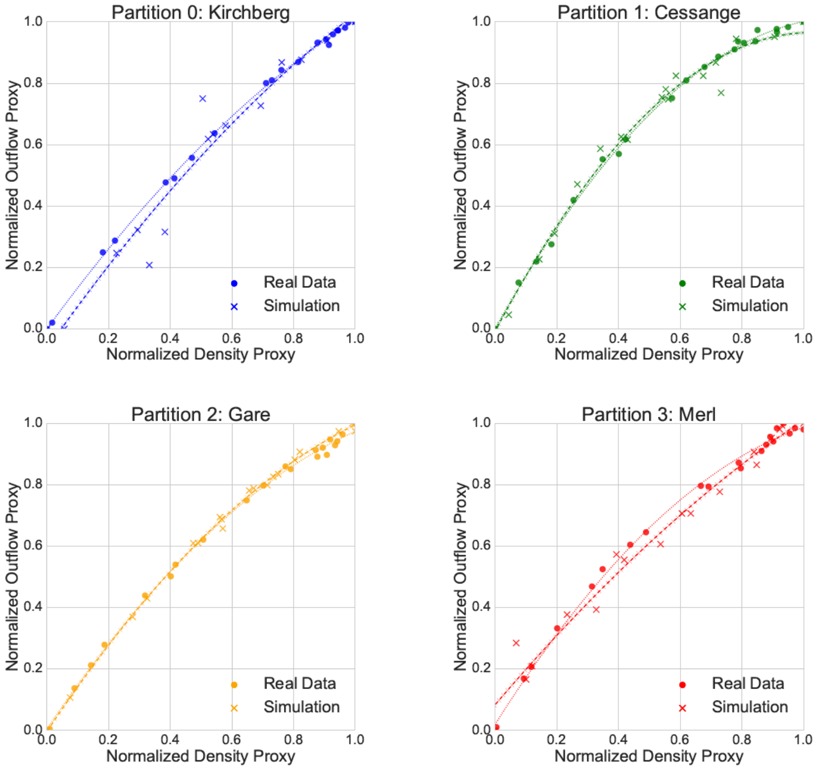

Figure 2. Comparison of Mobile Network MFD approximations

Figure 2 gives a comparison of the results for both simulation and real case study. Density Proxy is estimated based on the number of handovers internal to the cluster, while Outflow Proxy is estimated using the handovers out of the cluster. As one can see, all partitions show consistent and well-defined relations. Note that the network of Luxembourg City is hardly affected by significant congestion propagation and has no gridlock issues, hence the results show only the left branch of a Macroscopic Fundamental Diagram.

These results are very encouraging as they show that the presented methodology is able to capture the traffic dynamics independently from the moving-to-stationary user ratio, at least in the low-to-moderate congestion situations given in Luxembourg City. The full paper will also show results of simulations where the demand is significantly increased to create more significant congestion patterns.

References

[1] N. Geroliminis and C. F. Daganzo, "Existence of urban-scale macroscopic fundamental diagrams: Some experimental findings," *Transportation Research Part B: Methodological*, **42**(9):759-770, 2008.

[2] N. Geroliminis, J. Haddad, and M. Ramezani, "Optimal perimeter control for two urban regions with macroscopic fundamental diagrams: A model predictive approach," *IEEE Transactions on Intelligent Transportation Systems*, **14**(1):348-359, 2013.

[3] H. Bar-Gera, "Evaluation of a cellular phone-based system for measurements of traffic speeds and travel times: A case study from Israel," *Transportation Research Part C: Emerging Technologies*, **15**(6):380-391, 2007.

[4] N. Caceres, L. M. Romero, F. G. Benitez, and J. M. del Castillo, "Traffic flow estimation models using cellular phone data," *IEEE Transactions on Intelligent Transportation Systems*, **13**(3):1430-1441, 2012.

[5] L. Codeca, R. Frank, S. Faye, and T. Engel, "Luxembourg SUMO Traffic (LuST) Scenario: Traffic Demand Evaluation," *IEEE Intelligent Transportation Systems Magazine*, **9**(2): 52-63, 2017.

[6] D. Krajzewicz, J. Erdmann, M. Behrisch, and L. Bieker, "Recent development and applications of SUMO - Simulation of Urban MObility," *International Journal On Advances in Systems and Measurements*, **5**(3&4): 128-138, 2012.

[7] Derrmann, T., Frank, R., Engel, T., and Viti, F. (2017a). How mobile phone handovers reflect urban mobility: A simulation study. In 2017 5th IEEE International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), pages 486-491.

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