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Data fusion from real-time and historical trajectories for the microscopic traffic flow simulation of the campus of the University of the Bundeswehr Munich

Dr.-Ing. Eftychios Papapanagiotou [a]*, Oytun Arslan M.Sc. [a], Univ.-Prof.'in Dr.-Ing. Silja Hoffmann [a]

[a] *Professur für Intelligente, multimodale Verkehrssysteme, Universität der Bundeswehr München, Germany*

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This work addresses the following topic(s) from the Call for Contributions:
(Please check at least one box)

☐ Placemaking to integrate urban spaces and mobility
☐ Promoting sustainable mobility choices in metropolitan regions
☐ Governing responsible mobility innovations
☐ Shaping the transition towards mobility justice
☒ System analysis, design, and evaluation
☐ other: _____

Extended Abstract

Problem statement

In the era of Smart Cities and emerging technologies, Digital Twins are used to understand complex urban environments and model various future scenarios. To model the diverse traffic behavior of all traffic participants and their interactions, traffic engineers and researchers use microscopic traffic flow simulation tools. A credible representation of all traffic movements depends heavily on the reliable calibration and validation of these models with appropriate traffic data. The rapid advances in object recognition through Artificial Intelligence allow the collection of detailed individual trajectories and open new possibilities for deeper understanding and precise modeling.

The research project MORE (“Munich **Mo**bility **Re**search Campus”) is financed through dtec.bw (dtec.bw-Zentrum für Digitalisierungs- und Technologieforschung der Bundeswehr) and aims to utilize the campus of the University of the Bundeswehr Munich as a real laboratory for mobility research (MORE, 2023). In the scope of MORE, a camera-based traffic data collection system is installed, that gathers the trajectories of all traffic participants for offline and online analysis. The collected data is used for diverse simulation purposes, such as emission modeling, safety analysis and optimization of on-demand shuttle operation.

On the one hand, the traffic measurements from the cameras allow the calculation of a wide range of traffic data parameters. On the other hand, each simulation use case has its own traffic data requirements. To enable the correct calibration and validation of the simulation model of the campus for all use cases, the accuracy of the collected traffic data must be examined. Moreover, to accommodate all (simulation) use cases, with their different data requirements, the implementation of data fusion techniques is essential for the successful research and development in MORE.

* *Corresponding author. Tel.: +49 89 6004 3373.*
E-mail address: eftychios.papapanagiotou@unibw.de

Research objectives

This work aims to give insights for cities that (plan to) utilize cameras and simulations to understand better traffic demand and optimize traffic supply. The functionalities of all traffic management and control systems for traffic supply optimization can be divided into four main categories (PAPAGEORGIOU, 1998): collection of measurements, data fusion, decision-making and actuation of measures.

The presented work focuses on the first two categories and tries to answer the following two research questions:

- What is the accuracy of the traffic measurements from the trajectory-based data collection system of the campus of the University of the Bundeswehr Munich?
- What is the potential of data fusion of (historical and real-time) trajectories for the calibration and validation of the multifaceted microscopic traffic simulation of the campus of the University of the Bundeswehr Munich?

Methodological approach

The campus of the University of the Bundeswehr Munich offers a great real laboratory environment for mobility research. Around 3,500 students and 2,000 employees (researchers, professors, civil and military personnel) are currently registered at the University of the Bundeswehr Munich (UNIVERSITÄT DER BUNDESWEHR MÜNCHEN, 2023). This ensures both typical (e.g., rush hour with mixed traffic) and unique (e.g., Sunday evening returns) urban mobility patterns on the campus.

Inside the campus of the university there are 22 installed cameras that collect trajectories at the most important intersections. The cameras are connected to a server where the state-of-the-art video analysis software FLOW from DataFromSky runs. FLOW is created for online (real-time) analysis but also enables offline (historical) analysis. The real-time analysis takes place mainly through an Application Programming Interface (API). For the historical analysis the software TrafficSurvey Viewer from DataFromSky is used to evaluate the historical trajectories (RCE SYSTEMS , 2023). **Figure 1** shows an example view of the traffic data collection system on the campus with the software FLOW.

To answer the two main research questions the following tasks are fulfilled:

Trajectory-based traffic measurements

- Collection of traffic measurements from cameras.
- Collection of ground truth measurements with manual counting or other sensors.
- Comparison and evaluation of the quality of the traffic measurements with statistical methods.

Trajectory-based data fusion

- Definition of typical traffic parameters for calibration and validation based on the examined simulation use cases.
- Definition of the available traffic parameters from the installed cameras (historical and real-time analysis).
- Evaluation of the data fusion algorithm, depending on the data availability and the examined simulation use cases.

The examined data fusion algorithm is based on the established Extended Kalman Filter (EKF) (KALMAN, 1960) (LINT, 2012). The presented algorithm was originally developed as data fusion algorithm for traffic signal control with focus on optimization of vehicle flows (PAPAPANAGIOTOU, 2021). In the current work, the algorithm will be evaluated at non-signalized intersections with all traffic modes for the purpose of feeding the microscopic traffic flow simulation network of the University of the Bundeswehr Munich.

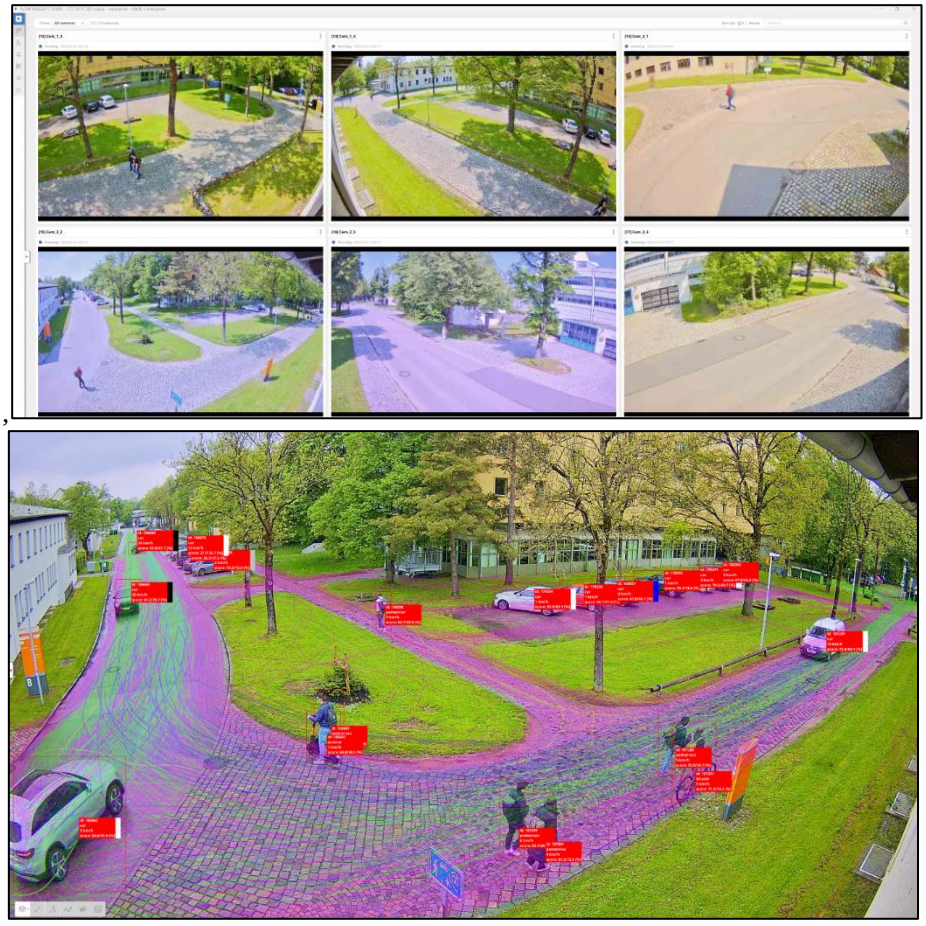

Figure 1: The traffic data collection system in the research project MORE

(Expected) results

The thorough evaluation of the traffic measurements and their fusion should give some new insights into the potential of camera-based data collection systems not only for microscopic traffic flow simulations but also for traffic management and control. Furthermore, especially difficult to detect traffic modes, such as e-scooter and large groups of pedestrians, will be examined under different traffic, weather and illumination conditions.

Trajectory-based traffic measurements

With the evaluation of the traffic measurements, it is expected to calculate the variance of the traffic measurements from the cameras in comparison with the ground truth, with the help of performance measures/indicators such as the Root Mean Square Error (RMSE) (EUROPEAN COMMISSION, 2023). Moreover, the measurement noise covariance that is needed for the implementation of the Extended Kalman Filter will be estimated (WELCH, 2001).

Trajectory-based data fusion

To facilitate the data fusion, a certain functional workflow and technical communication should be established between the modules. The implemented functional and technical architecture of the trajectory-based data collection system will be presented as a reference architecture (KLEIN, 2018). Furthermore, to assess the suitability of the proposed EKF-based algorithm, both its estimation and prediction capabilities will be examined. The relevant (estimated and predicted) traffic parameters from an appropriate number of simulation runs will be compared against the actual values from the field measurements (DAAMEN, et al., 2015).

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