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A Two-Level Stochastic Model for the Lateral Movement of Vehicles Within Their Lane Under Homogeneous Traffic Conditions

paper link

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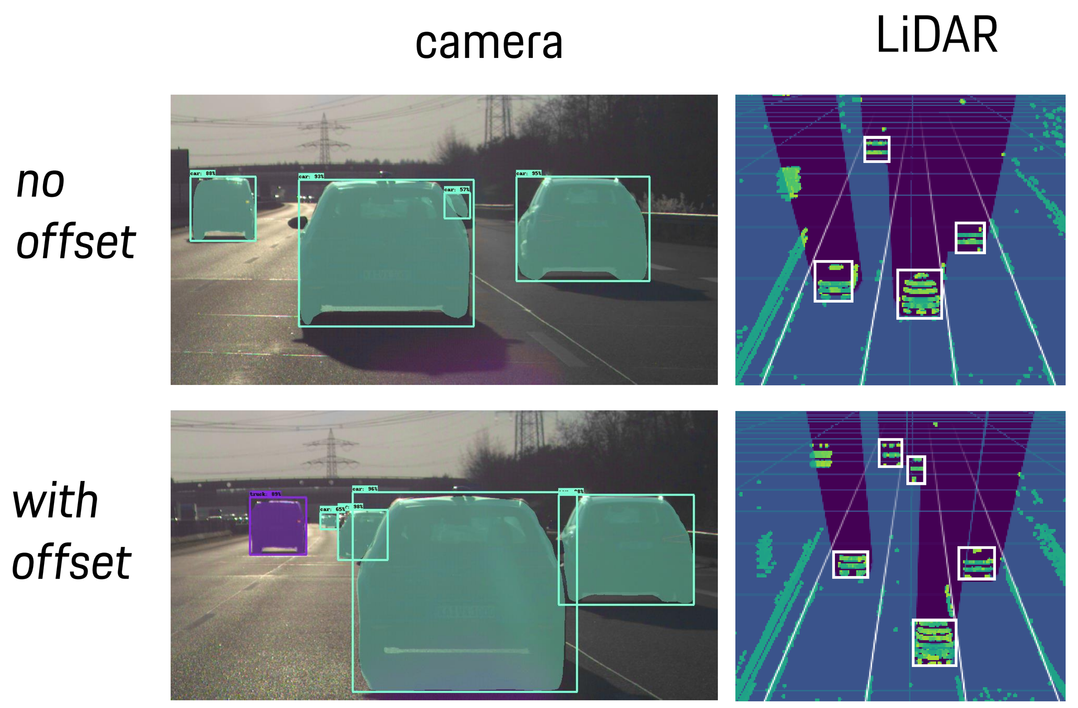
Nicole Neis[1,3], Jürgen Beyerer[2,3]

[1]Porsche Engineering Group GmbH, 71287 Weissach, Germany, nicole.neis@porsche-engineering.de, [2]Fraunhofer IOSB, 76131 Karlsruhe, Germany,
[3]Karlsruhe Institute of Technology (KIT), Vision and Fusion Laboratory (IES), 76131 Karlsruhe, Germany

Motivation

Effect of the lateral movement of vehicles within their lane on the range of vision of vehicle sensors



→ Important to consider the lateral movement within simulations used for the virtual validation of automated driving functions via so called submicroscopic behavior models

Related Work

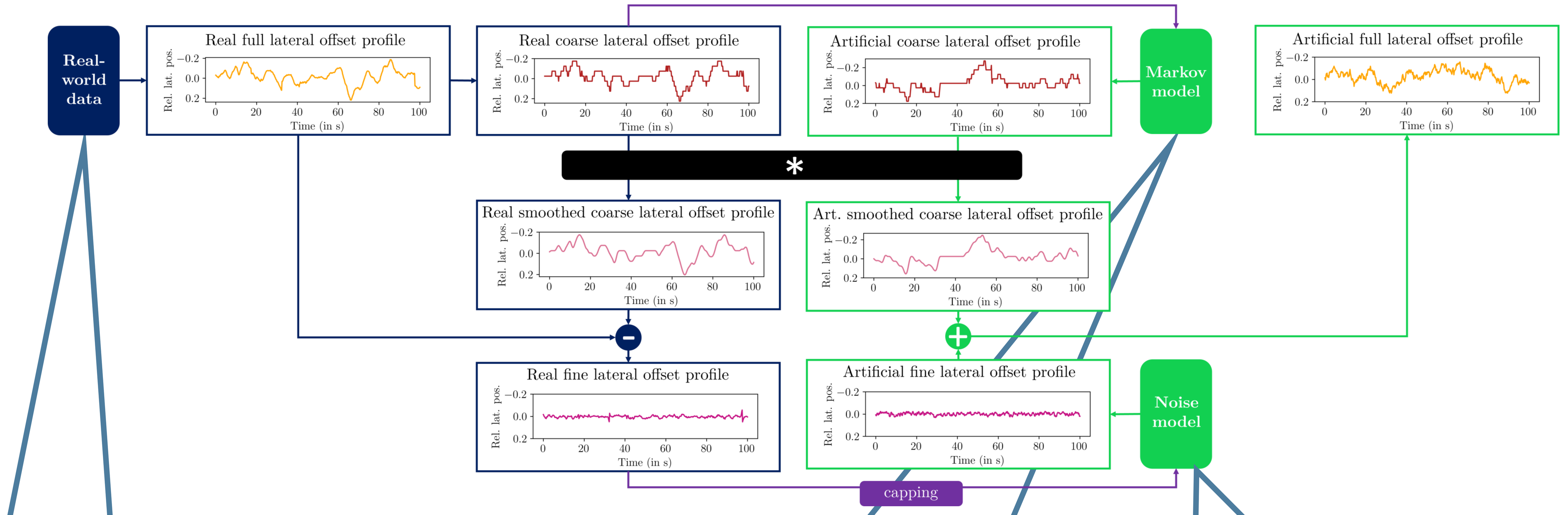
- Existing microscopic traffic simulation tools neglect lateral movement except for lane changes [1] or target heterogeneous traffic conditions [2]
- Only a few submicroscopic behavior models enabling continuous lateral movement under homogeneous traffic conditions are proposed in literature [3,4]
- All calibrated based on NGSIM dataset, thus model only general (not driver-specific) behavior and are restricted to short-term data, might be affected by inaccuracies in data

Model

Applicability: Highways under free flow traffic conditions (velocities higher than 40 km/h), Lane following maneuvers (as opposed to lane changes)

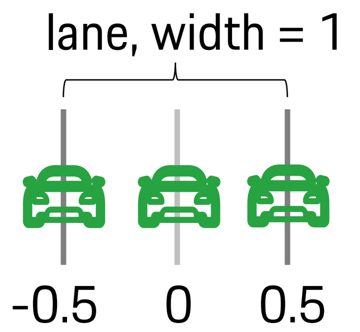
Core Idea: For time steps i lateral movement $x(i)$ is given as $x(i) = \kappa(i) + \phi(i)$ with

- *Coarse movement* $\kappa(i)$*:* discrete lateral position, systematic behavior
- *Fine movement* $\phi(i)$*:* continuous behavior, stochastically independent from coarse



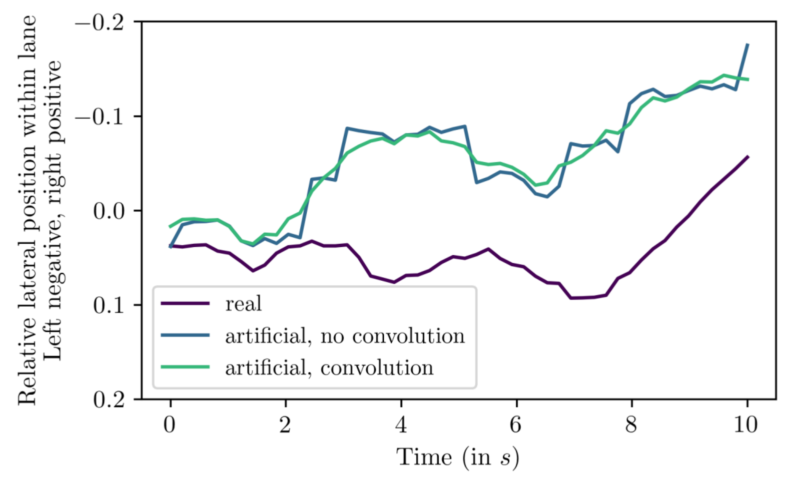
Dataset

- Two real-world datasets recorded on German highways with a Porsche Cayenne as described in [5]
- Each tour driven by single (but different) driver
- Ca. 50 min usable data/dataset
- Use of relative lateral position:



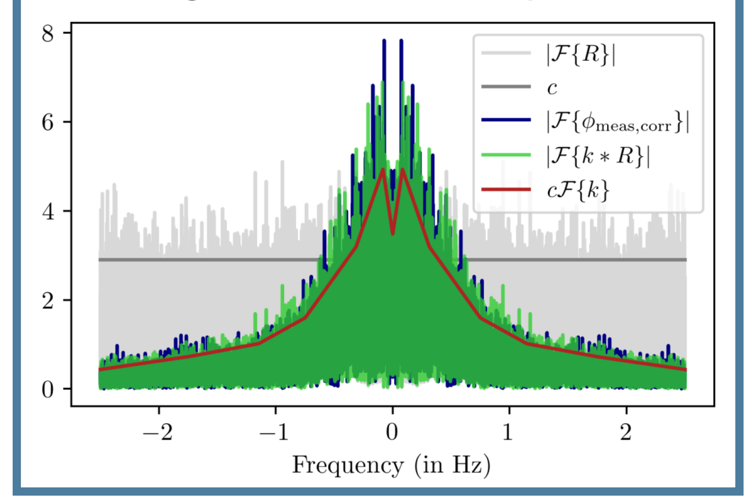
Markov model

- Coarse movement $\kappa(i)$ via Markov chain over n_c segments of width $^1/_{n_c}$
- Resulting in step function, whose jumps cannot be compensated by fine movement
- Thus, convolution with kernel g_s: : $\kappa = \hat{\kappa} * g_s$



Noise model

- Capping to achieve stochastic independence giving $\phi_{meas,corr}$
- Modelling of fine movement via $\phi = R * k$ with R white noise, k a convolution kernel
- Fitting within Fourier space:



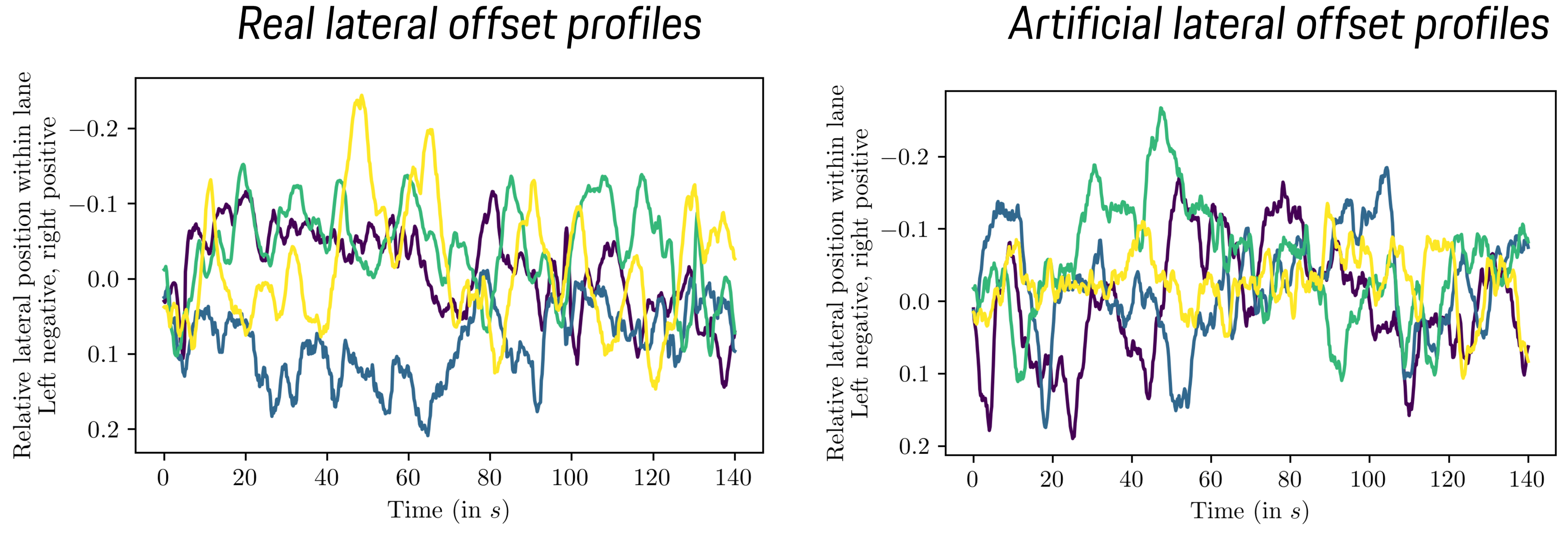
Results

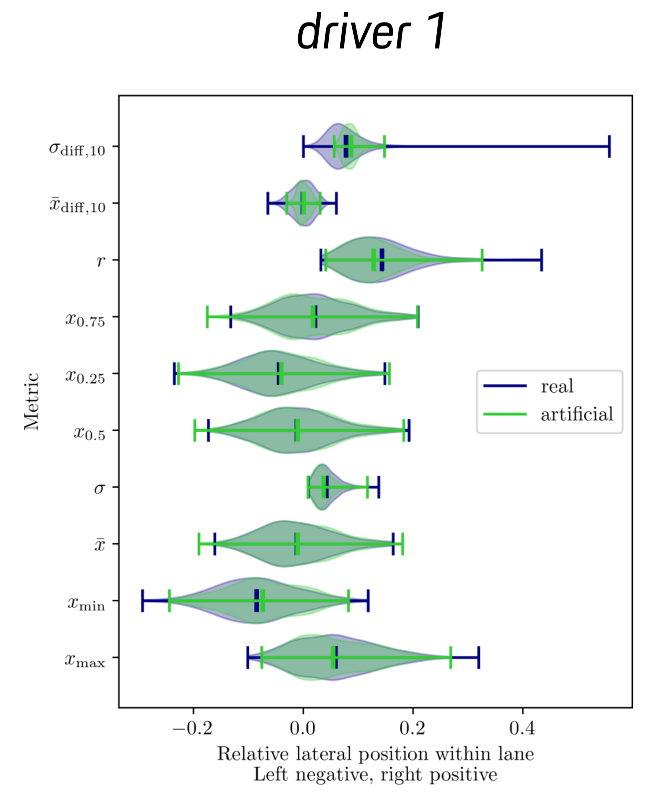
Runtime: 10 000 times faster than real time

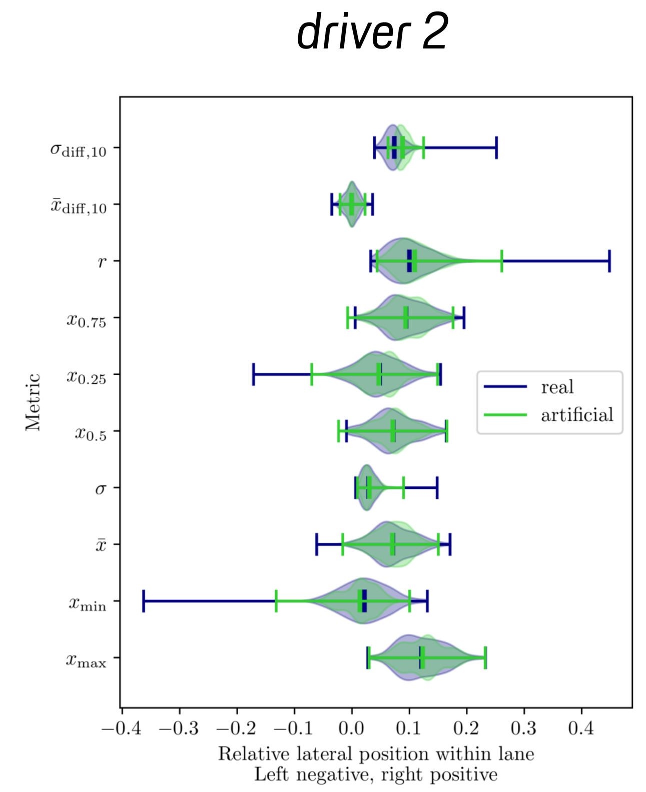
Quantitative results: evaluation of real and artificial lateral offset snippets $X = [x_0, \dots, x_m]$ of 10 s duration using ten metrics for two different model calibrations (one per single-driver dataset)

Metrics on X: x_{max} (maximum), x_{min} (minimum), $\bar{x}$ (mean), σ (standard deviation), $x_{0.5}$ (median), $x_{0.25}$ (25 % percentile), $x_{0.75}$ (75 % percentile), r (range), $\bar{x}_{diff,10}$ (10x mean difference of two consecutive values), $\sigma_{diff,10}$ (10x standard deviation of difference of two consecutive values)

Qualitative results (same color = same start position)







Conclusion

- Development of two-level stochastic model for the lateral movement of vehicles within their lane under homogeneous traffic conditions
- Good agreement for eight out of the ten metrics
- Capable to cover characteristics of different tours
- Extremely fast (10 000 times real time)
- Currently only considering general lateral movement
- Next steps are enhancement to consider other influences on lateral offset behavior such as vehicles on neighboring lanes, longitudinal velocity of ego vehicle, etc.
- Improvement of metrics on difference of consecutive time steps

References

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