KI DATA TOOLING
The Data Kit for Automotive AI

Probabilistic Trajectory Forecast of Vulnerable Road User

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ML Function Development

Fig.1: Trajectory forecasting. The future trajectory of a VRU is forecasted based on past observations (© TH Aschaffenburg).

Abstract

In the context of driver assistance, an accurate and reliable prediction of a VRU trajectory is mandatory to reduce the risk of VRUs in traffic. We propose using probabilistic forecasts to model inherent uncertainties for reliable systems.

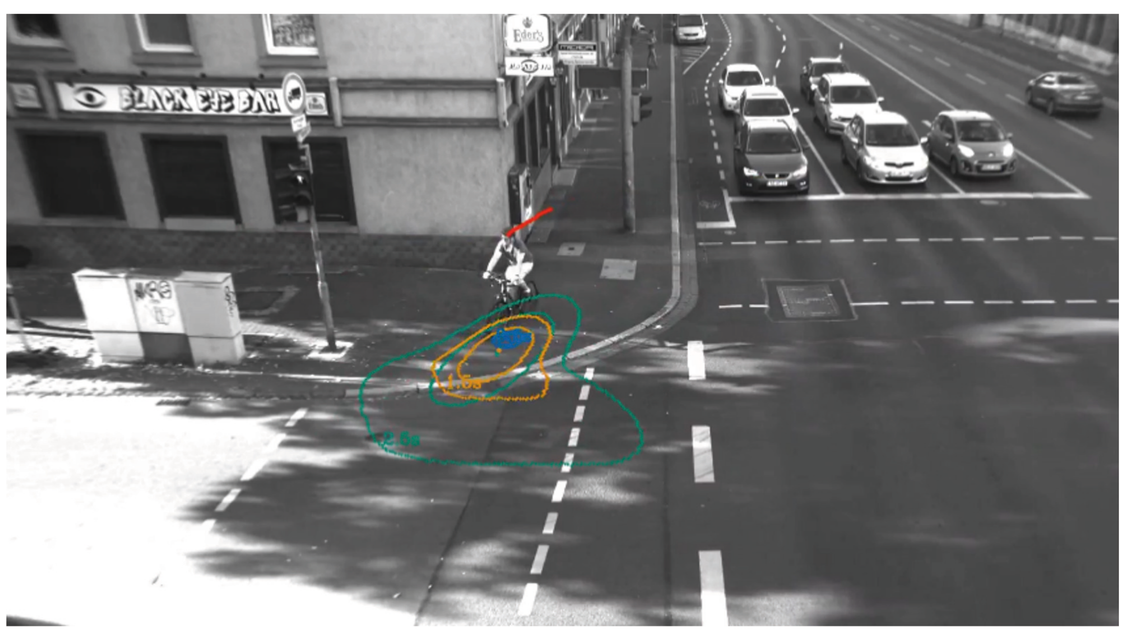

Fig.2: Probabilistic trajectory forecast of a cyclist in 0.5s, 1.5s, and 2.5s in the future (© TH Aschaffenburg).

Modeling Uncertainty by Probabilistic Forecasts

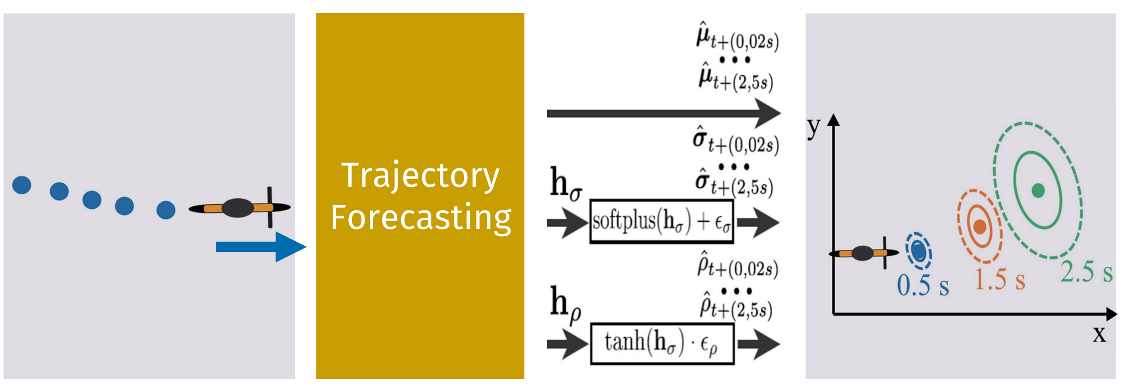

Fig.3: Unimodal trajectory forecasting

- Method form [1] adds uncertainty estimates to deterministic forecasts
- Simple neural network
- Trained on future ground truth (GT) positions only in ego coordinates
- Learns uncertainty from data (semi-supervised)

Ambiguity and Multi-modality

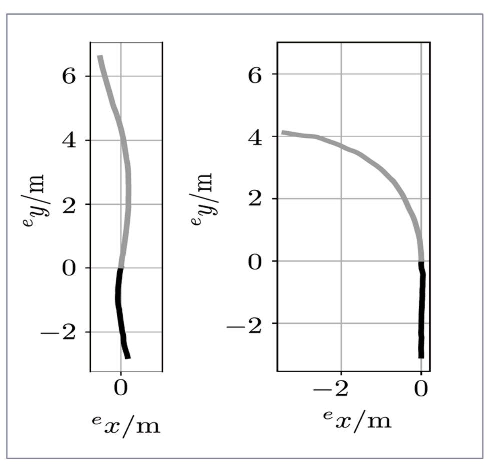

Fig.4: Example trajectories for cyclists. Despite similar observed trajectories (black lines), the future trajectories are very different (© TH Aschaffenburg).

Multi-modality is needed!

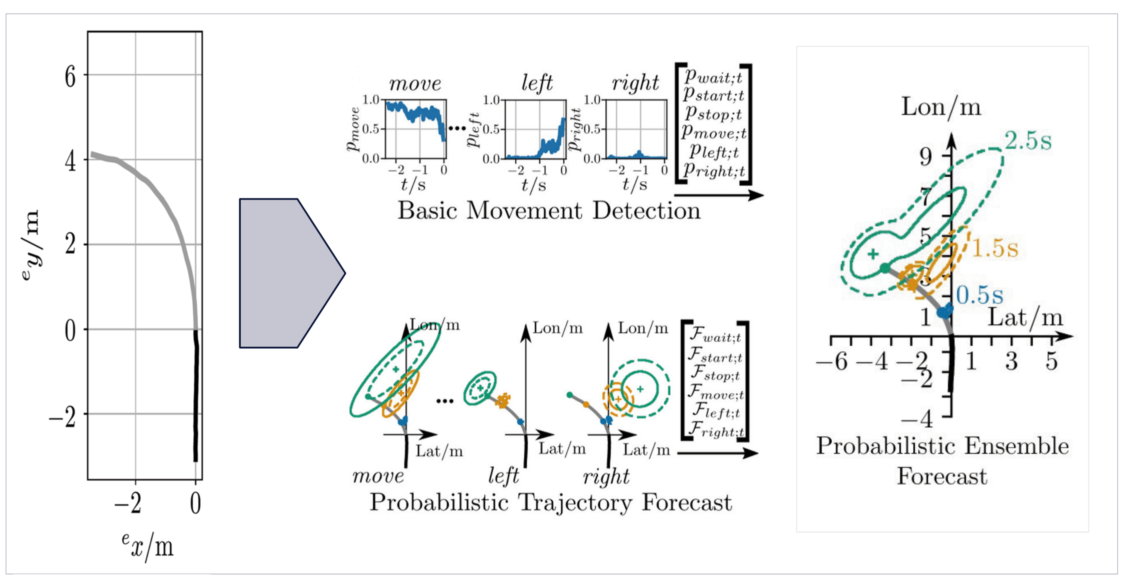

Fig.5: Ensemble of probabilistic trajectory forecast. (© TH Aschaffenburg).

- Unimodal forcaster from [1] does not take the issue from Fig. 4 into account, resulting in unreliable forecasts
- In [2] a multi-modal ensemble is proposed to resolve this issue (see Fig. 5)

Evaluation

[2] contributes two new metrics for evaluation of probabilistic forecaster:

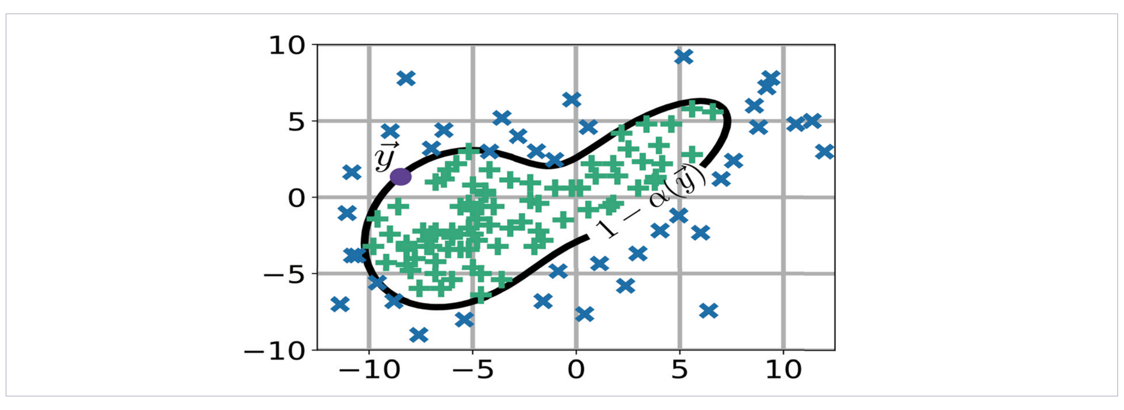

Fig.6: Confidence estimation for arbitrary points and distributions. (© TH Aschaffenburg).

Reliability

- The idea of "reliability" conveys information about whether the user can rely on the forecast for decision making
- For 10% of the predictions the GT lies in the 10% confidence region, for 20% of the cases in the 20% region, and so on

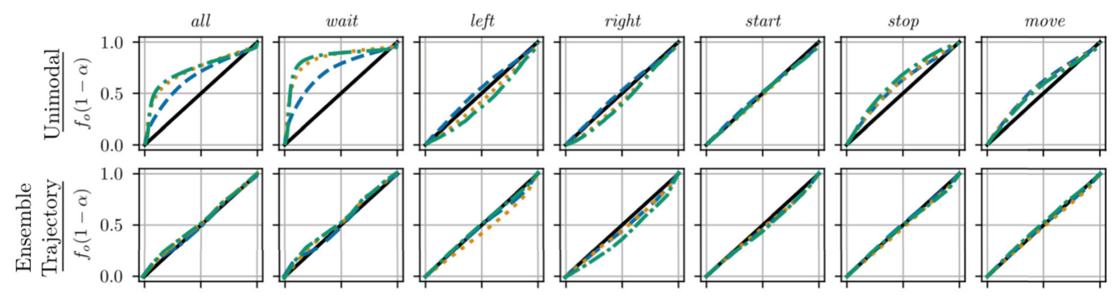

Fig.7: Reliability evaluation by calibration plots. (© TH Aschaffenburg).

Sharpness

- Sharpness is defined as the forecasted area in m² of confidence regions
- For downstream tasks like planning: the smaller, the better

	Unimodal							Ensemble Trajectory Based						
	all	*wait*	*left*	*right*	*start*	*stop*	*move*	*all*	*wait*	*left*	*right*	*start*	*stop*	*move*
$\hat{\Gamma}$	0.44 (0.46)	0.66 (0.66)	0.20 (0.22)	0.24 (0.24)	0.23 (0.08)	0.29 (0.21)	0.25 (0.21)	**0.08 (0.07)**	**0.12 (0.10)**	0.14 **(0.15)**	0.07 (0.07)	0.07 **(0.06)**	**0.04 (0.05)**	0.05 **(0.04)**
$\overline{\Gamma}$	0.2 (0.2)	0.29 (0.29)	0.06 (0.07)	0.05 (0.08)	**0.02** (0.03)	0.10 (0.11)	0.07 (0.10)	**0.02 (0.02)**	**0.04 (0.03)**	0.06 **(0.06)**	0.04 (0.02)	**0.02 (0.02)**	**0.01 (0.02)**	0.02 (0.02)
$\overline{K}(0.68)$ in m^2/s	0.62 (0.73)	0.19 (0.25)	1.9 (2.39)	1.86 (2.20)	1.37 (1.69)	0.97 (1.16)	**1.52** (1.73)	0.41 (0.36)	**0.02 (0.02)**	**1.24** (1.37)	1.15 (1.21)	0.96 (1.03)	0.77 **(0.61)**	**1.53** (1.21)
$\overline{K}(0.95)$ in m^2/s	**1.62** (1.92)	**0.5 (0.65)**	4.99 (6.26)	4.87 (5.77)	3.58 (4.42)	2.55 (3.04)	**3.99** (4.55)	1.96 (1.88)	1.16 (1.17)	**3.60 (3.86)**	3.59 (3.63)	3.09 (3.29)	2.54 (2.19)	4.41 (3.66)
$\overline{K}(0.99)$ in m^2/s	**2.48 (2.93)**	**0.76 (0.99)**	7.61 (9.55)	7.43 (8.80)	5.47 (6.75)	3.89 (4.64)	6.09 (6.94)	3.32 (3.22)	2.03 (2.06)	**5.88 (6.29)**	7.15 (5.93)	5.21 (5.51)	4.30 (3.81)	7.15 (6.11)
ASAEE in m/s	0.22 (0.22)	0.10 (0.11)	0.59 (0.56)	0.61 (0.51)	0.48 (0.48)	0.34 (0.31)	**0.45 (0.39)**	**0.21 (0.21)**	**0.08 (0.09)**	**0.47 (0.55)**	**0.43 (0.44)**	0.52 (0.51)	**0.31 (0.28)**	0.47 (0.41)

Tab 1: Evaluation of reliability, sharpness, and mode position accuracy. (© TH Aschaffenburg).

References:

[1] S. Zernetsch, H. Reichert, V. Kress, K. Doll and B. Sick, "Trajectory Forecasts with Uncertainties of Vulnerable Road Users by Means of Neural Networks," 2019 IEEE Intelligent Vehicles Symposium (IV), Paris, France, 2019, DOI: 10.1109/IVS.2019.8814258.

[2] S. Zernetsch, H. Reichert, V. Kress, K. Doll and B. Sick, "A Holistic View on Probabilistic Trajectory Forecasting – Case Study. Cyclist Intention Detection," 2022 IEEE Intelligent Vehicles Symposium (IV), Aachen, Germany, DOI: 10.1109/IV51971.2022.9827220.

Partners

External partners

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