Validation by Design
Making Machine Learning for Autonomous Driving Interpretable and Validatable

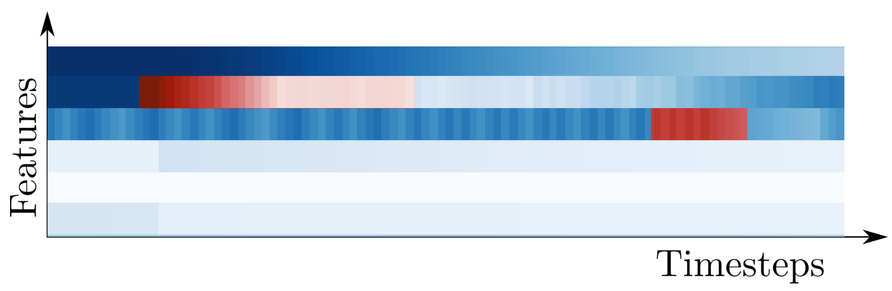
Research Question

- Is safe artificial intelligence in autonomous driving possible?
- How can foreseeable and interpretable behavior be ensured even before delivery?
- Can interpretability and performance of a machine learning (ML) algorithm be complementary?

Feature Generation Method [1]

- Use intrinsic properties of ML structures to establish interpretability.
- Best of both worlds: Fuse deep learning (Convolutional Neural Networks, Recurrent Architectures etc.) and classical methods (Random Forests, Mixture of Experts etc.) for best performance.
- Visualization as valuable byproduct: Applied interpretability methods generate visualizations for more insight.
- Layerwise Relevance Propagation highlights salient regions in input according to

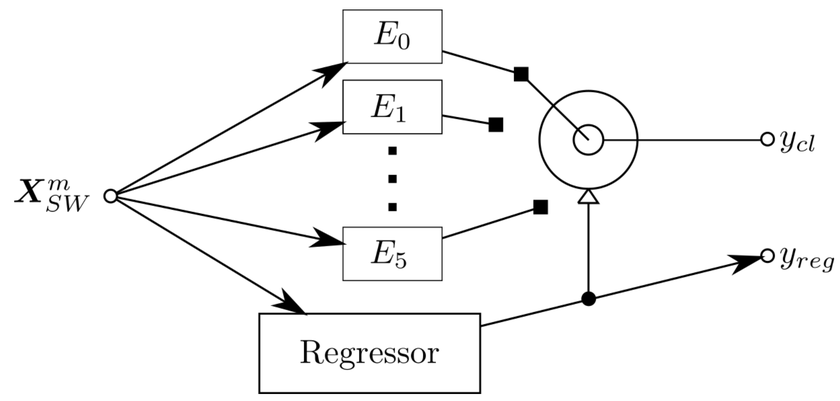
$$R_i^{(l)} = \sum_j \left(\alpha \cdot \frac{z_{ij}^+}{\sum_i z_{ij}^+} + \beta \cdot \frac{z_{ij}^-}{\sum_i z_{ij}^-} \right) R_j^{(l+1)}, \tag{1}$$



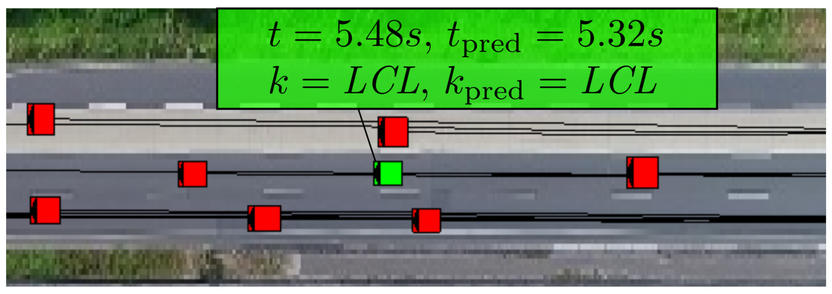
- Interpretable feature generation method facilitates enriched datasets wile remaining fully interpretable.

Mixture of Experts (MoE) Architecture [3]

- Early classification to improve driving comfort & safety
- Experts specialized on different prediction horizons.



- Interpretable expert classifiers, e.g. Decision Trees
- Small trees $\rightarrow$ better interpretability
- Focus of early experts: vehicle constellations
- Focus of late experts: acceleration profiles
- **Exemplary Lane Change Scenario**
  Maneuver: Lane Change Left (LCL)



- Regressor correctly assigns early expert
- Vehicle constellation: Slow leading vehicle, left lane fast
- Decision: Lane Change Left after current vehicle on lane passed

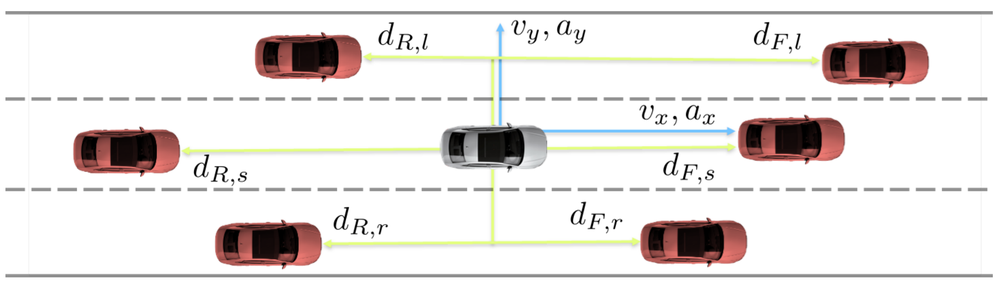
Dataset

- Public dataset highD [2] for reproducability
- Multivariate time series of lane changes
- Classification labels:
  Lane change direction left *LCL*, right *LCR* and no lane change *NLC*.
- Regression labels: Time to lane change in seconds.
- Dataset split 70/20/10 into training, validation and test set, containing samples according to

	LCR	NLC	LCR	Total
Training	1548	1548	1548	4644
Validation	449	449	449	1347
Test	209	209	209	627

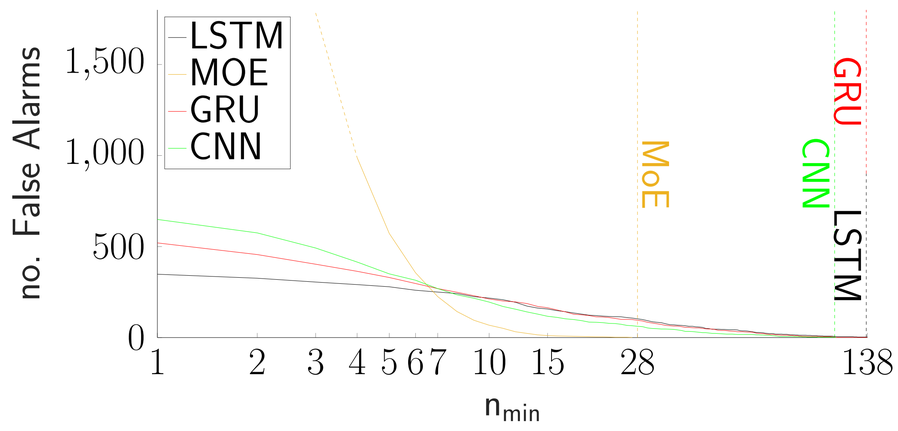
- Feature vector is describing the vehicle constellation and dynamic properties.
- A single sample with F features and T discrete timesteps is defined as

$$\boldsymbol{X}^m \in \mathbb{R}^{F \times T}, \tag{2}$$



Results

- End-to-end interpretable approach for early detection
- Smoothing by n_{min} subsequent identical decisions



- MoE false alarm rate outperforms reference methods
- Mean reliable prediction time μ_{trel} competitive with reference methods

Ref. Method	CNN	GRU	LSTM	MoE
False Alarms	62	95	103	0
μ_{trel}	3.89s	3.91s	3.84s	3.44s

References

[1] Oliver Gallitz et al. Interpretable feature generation using deep neural networks and its application to lane change detection. In *IEEE ITSC*, pages 3405–3411, 2019.

[2] Robert Krajewski et al. The highd dataset. In *IEEE ITSC*, pages 2118–2125, 2018.

[3] Oliver Gallitz et al. Interpretable machine learning structure for an early prediction of lane changes. Lecture Notes in Computer Science, pages 337–349. Springer, 2020.

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