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A HYBRID-AI APPROACH FOR COMPETENCE ASSESSMENT OF AUTOMATED DRIVING FUNCTIONS

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CONTEXT

- Automated driving functions rely on logic-based and **data-driven** algorithms.
- Deep Neural Network tends to be overconfident, especially in classification tasks [1].
  It cannot reason on whether it is competent in a given situation.

Report "Who's in control?", Dutch Safety Board

November 28th, 2019 The Hague

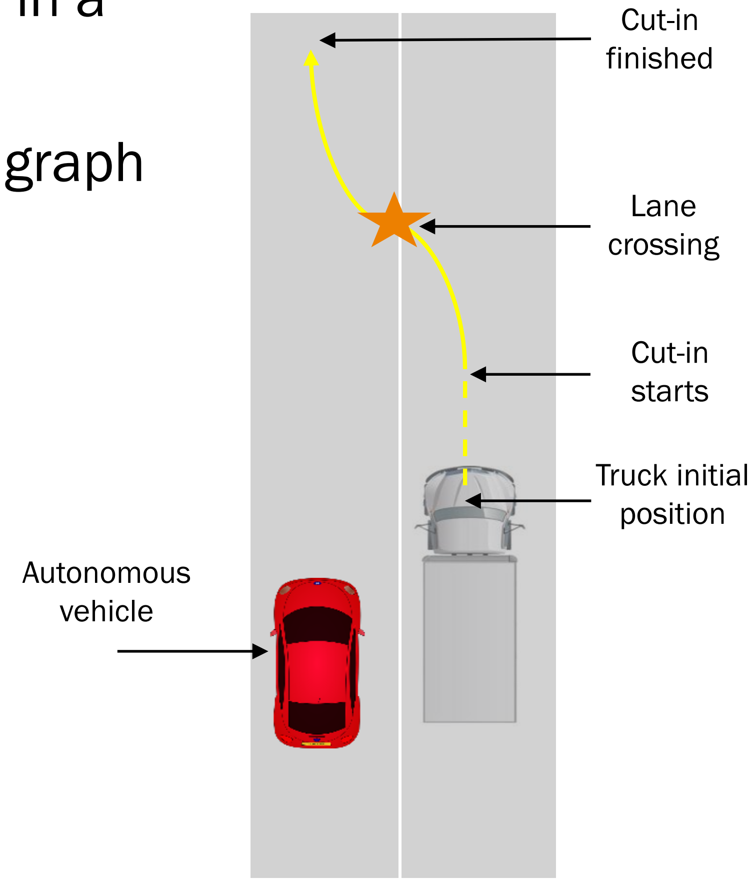
HYBRID AI [2]

- **Use case:** cut-in classification.
- **Goal:** competence assessment of a Deep Neural Network in a variety of situations.
- **Method:** coupling a data-driven approach to a knowledge graph to return an estimate of the classifier reliability.

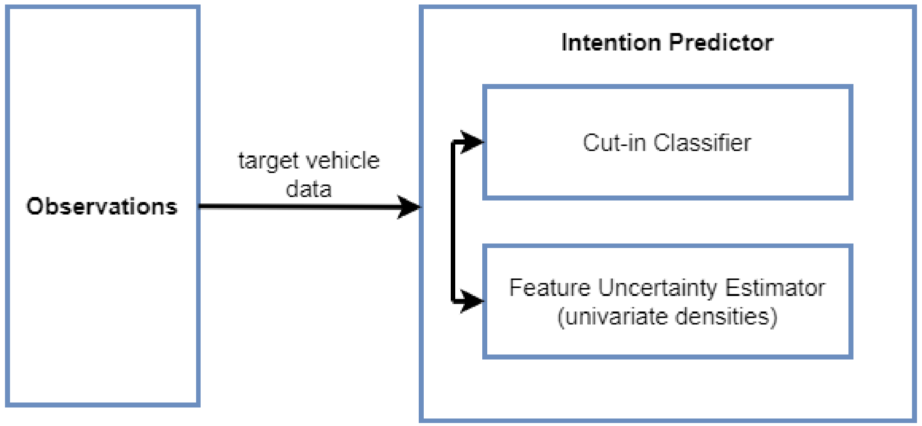
Hybrid AI

Data-driven
- Out-of-distribution analysis

Knowledge-driven
- Ontology-based knowledge graph



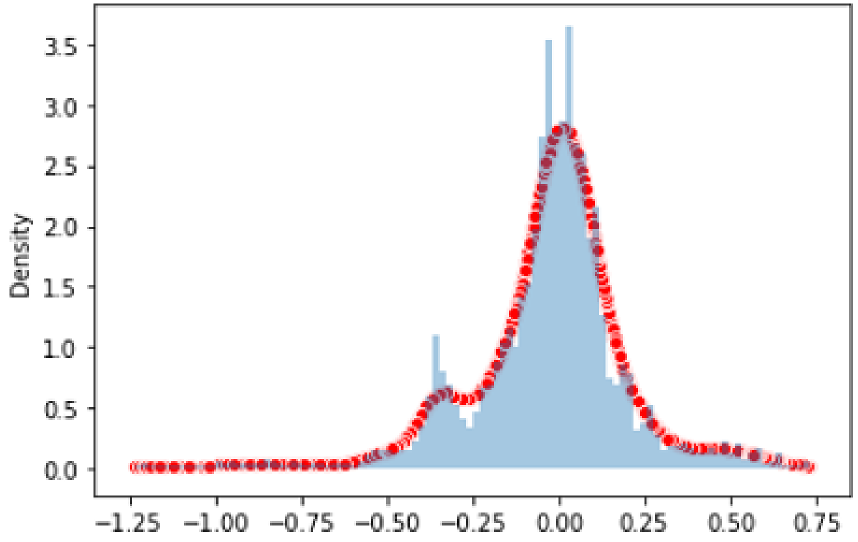
FRAMEWORK
PERCEPTION



FRAMEWORK
PERCEPTION

- **Feature Uncertainty Estimator** quantifies the extent to which an observation is out-of-distribution.

Density of feature *acceleration*

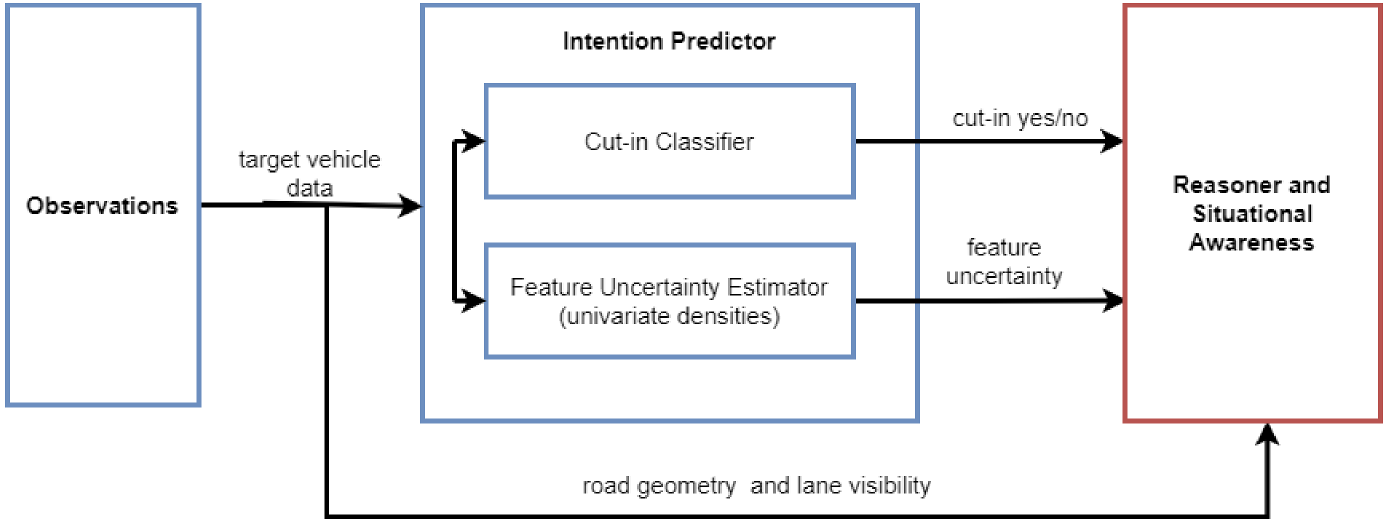


acceleration [$\frac{m}{s^2}$]

- We fit a Kernel Density Estimator (KDE) over all the features in the training data.
- We derive the normalized likelihood of a new observation *x*.

Deep Neural Networks underperform on out-of-distribution data.

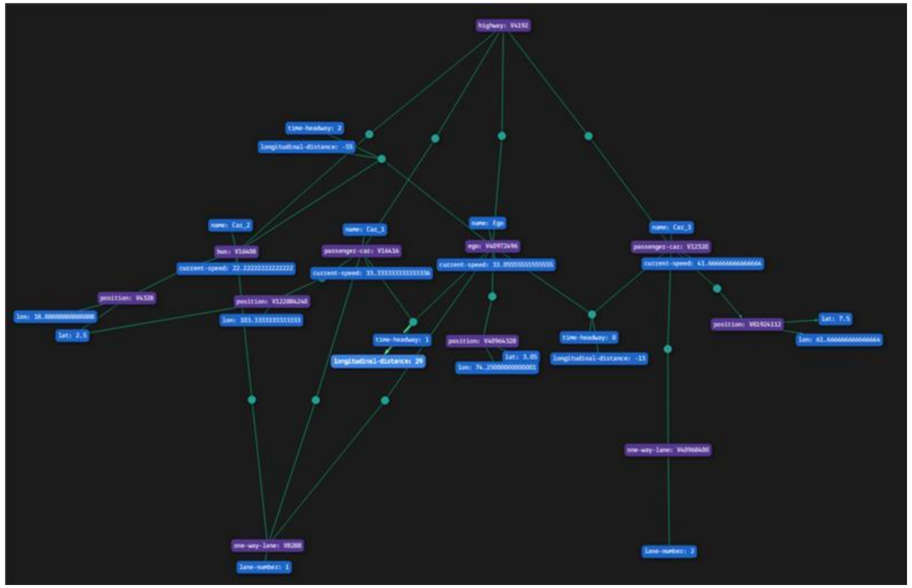
FRAMEWORK
REASONING



FRAMEWORK
REASONING

Reasoning relies on an **ontology-based knowledge graph.**

- ❑ Ontology allows to inject domain expert knowledge for semantic inference.
- ❑ The world is structured in *entities* [e.g. vehicle, lane] and *attributes* [e.g. visibility of the lane] connected via *relations* [e.g. drives_on_lane].



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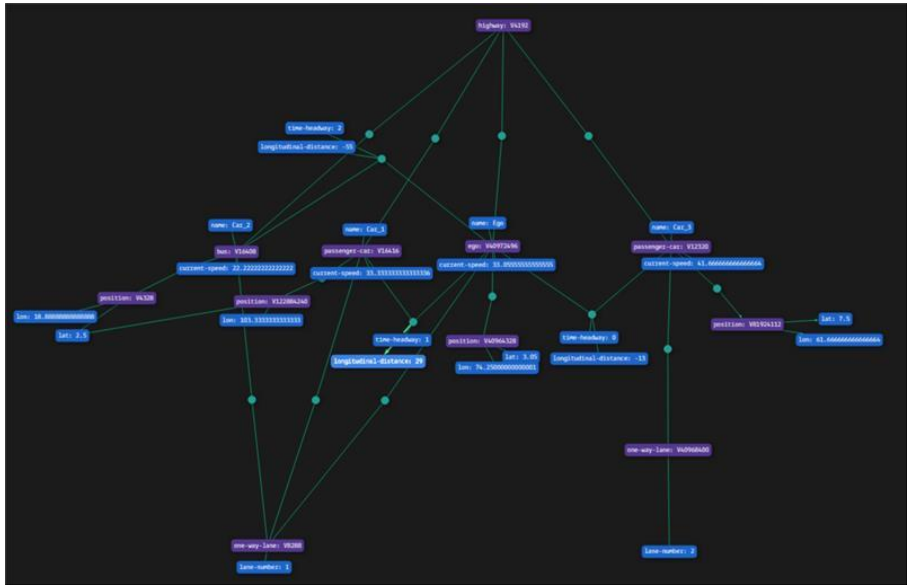
We adopted inference rules [3] to:

- Assign "*importance*" (categorical) and "*doubt*" (numerical) attributes to the entities and relations based on **domain knowledge.**
- Combine *importance* and *doubt* into a measure of *competence.*

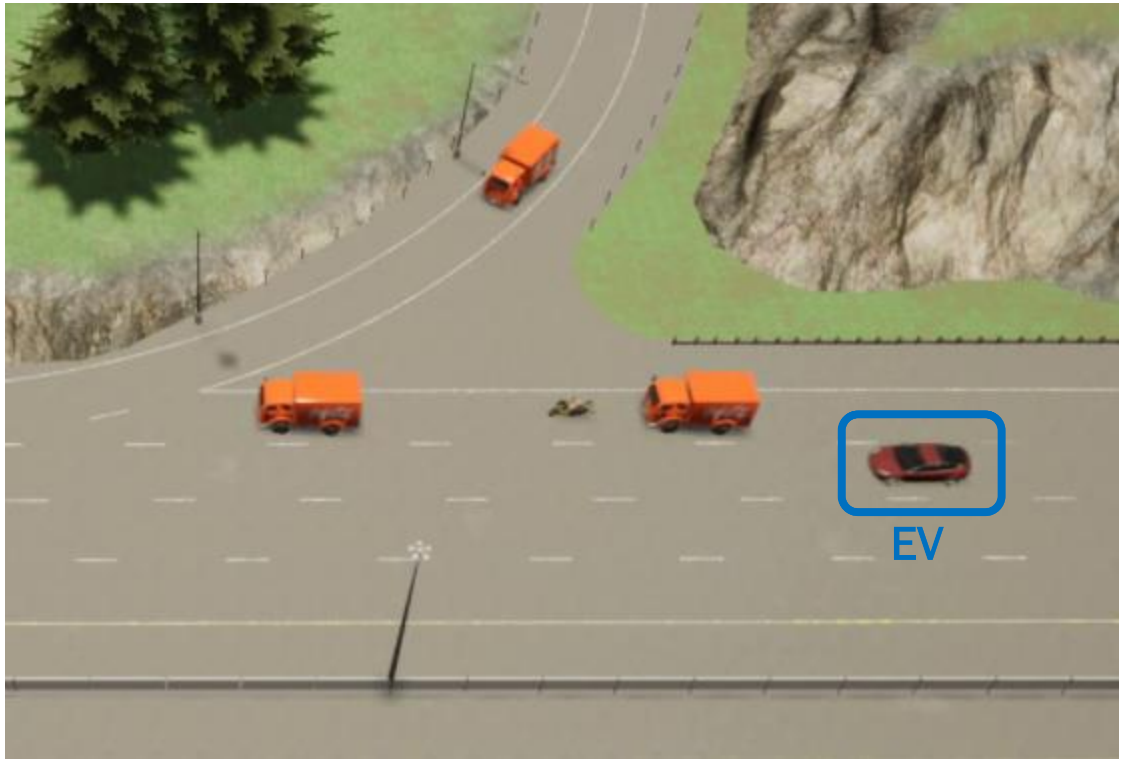


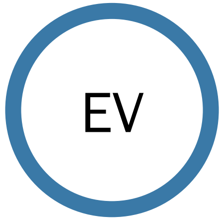
FRAMEWORK
REASONING

Importance → Risk posed

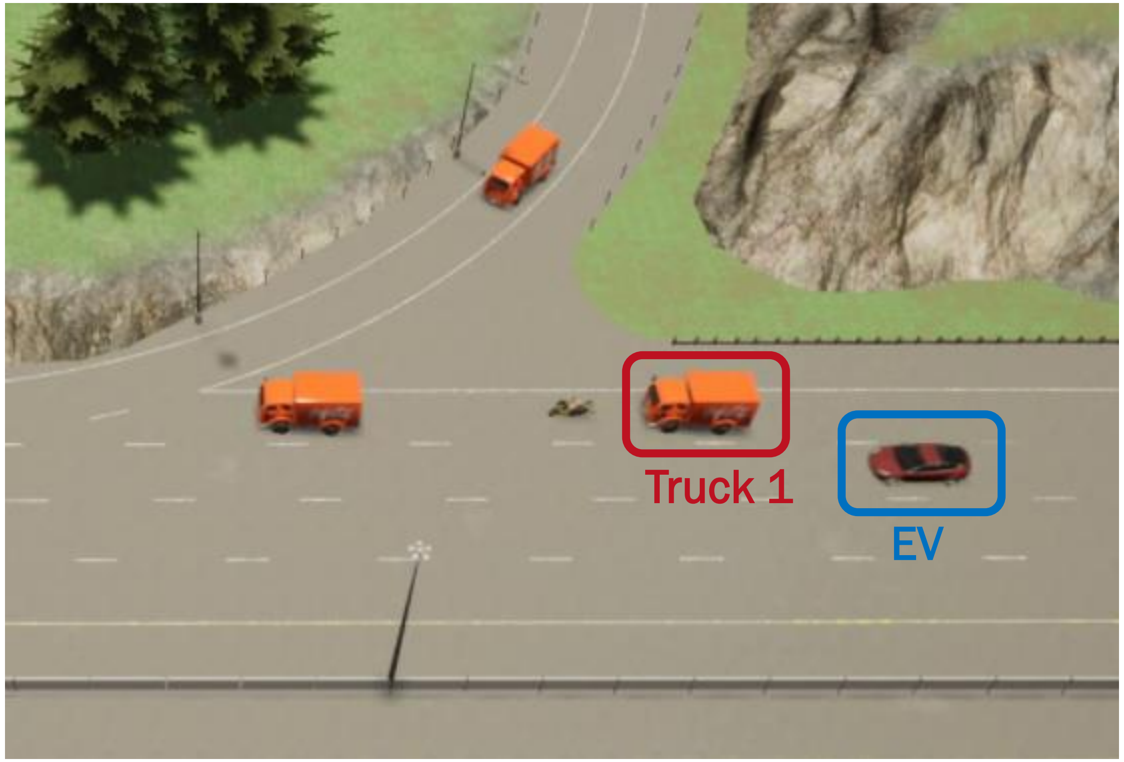
High

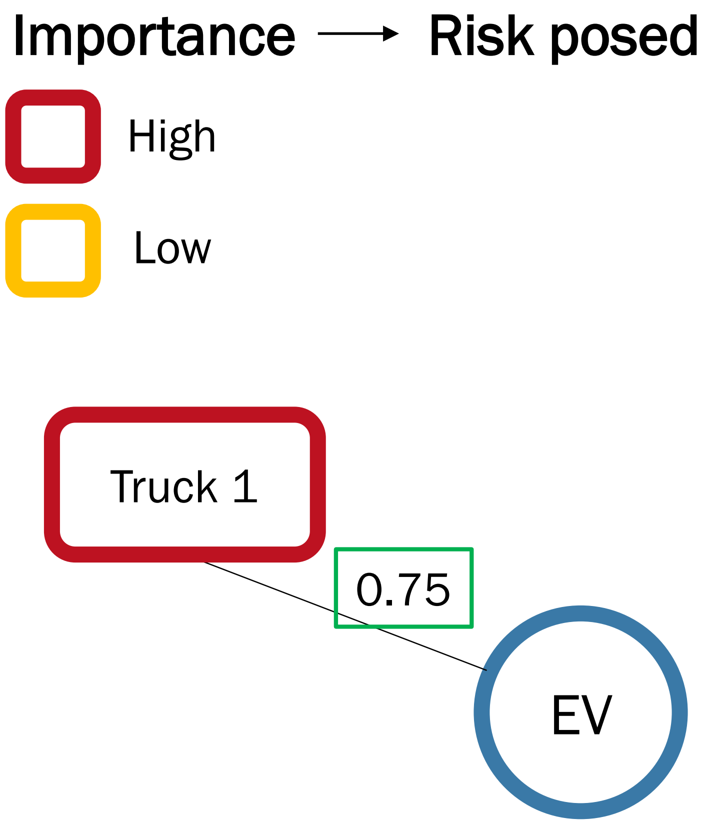
Low



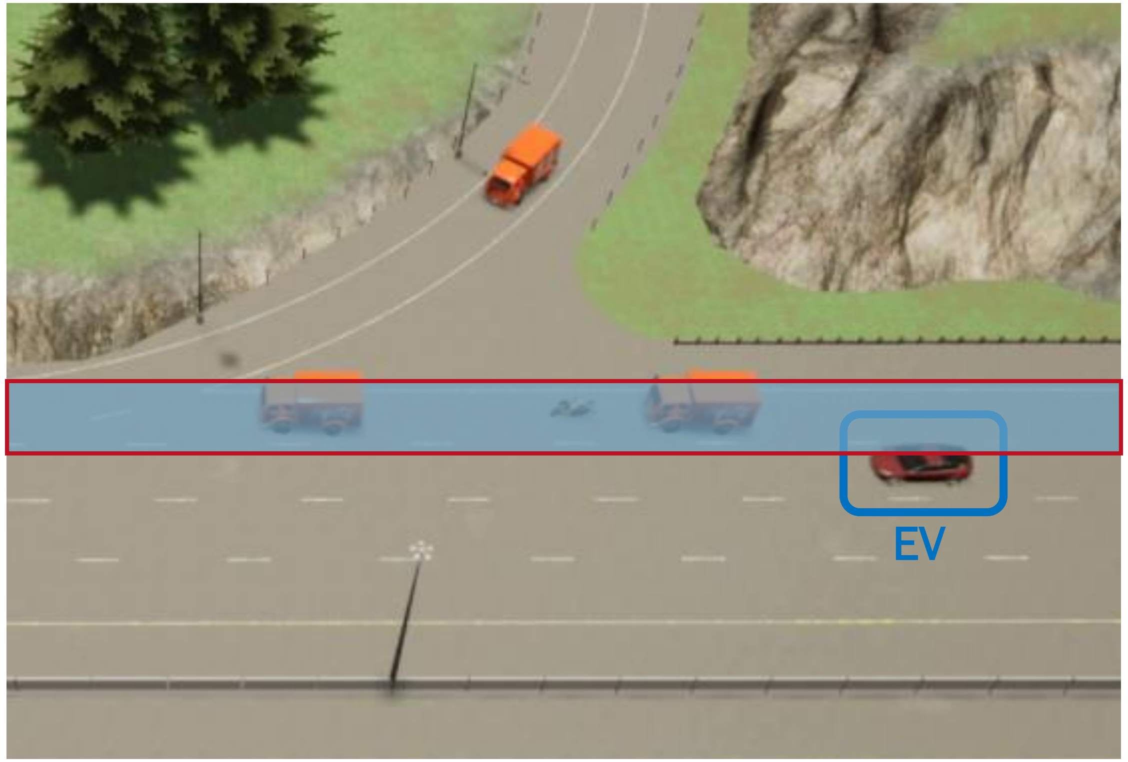


FRAMEWORK
REASONING





FRAMEWORK
REASONING



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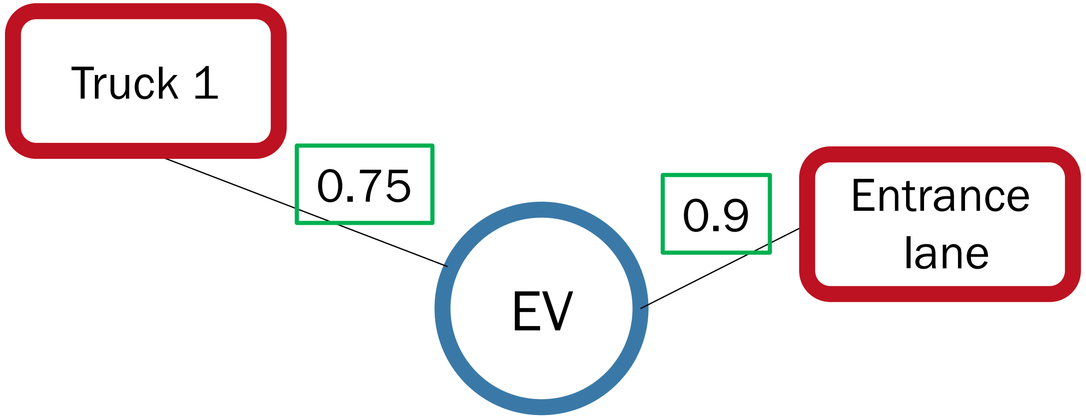
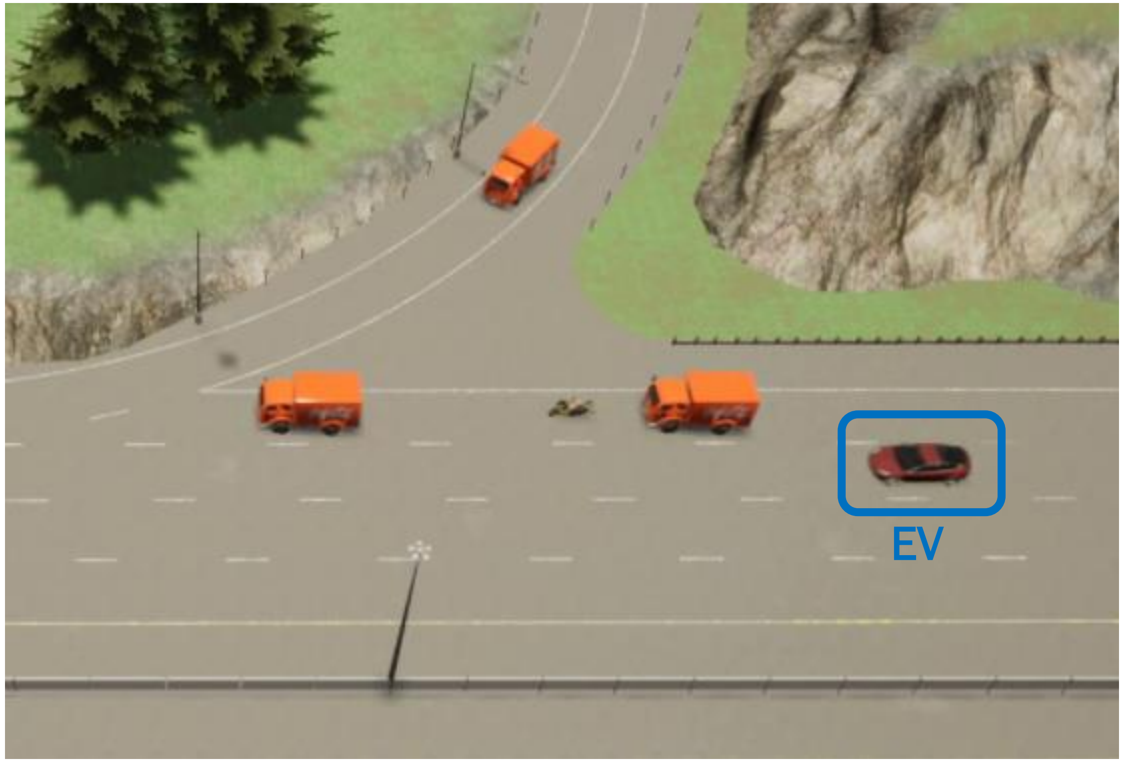
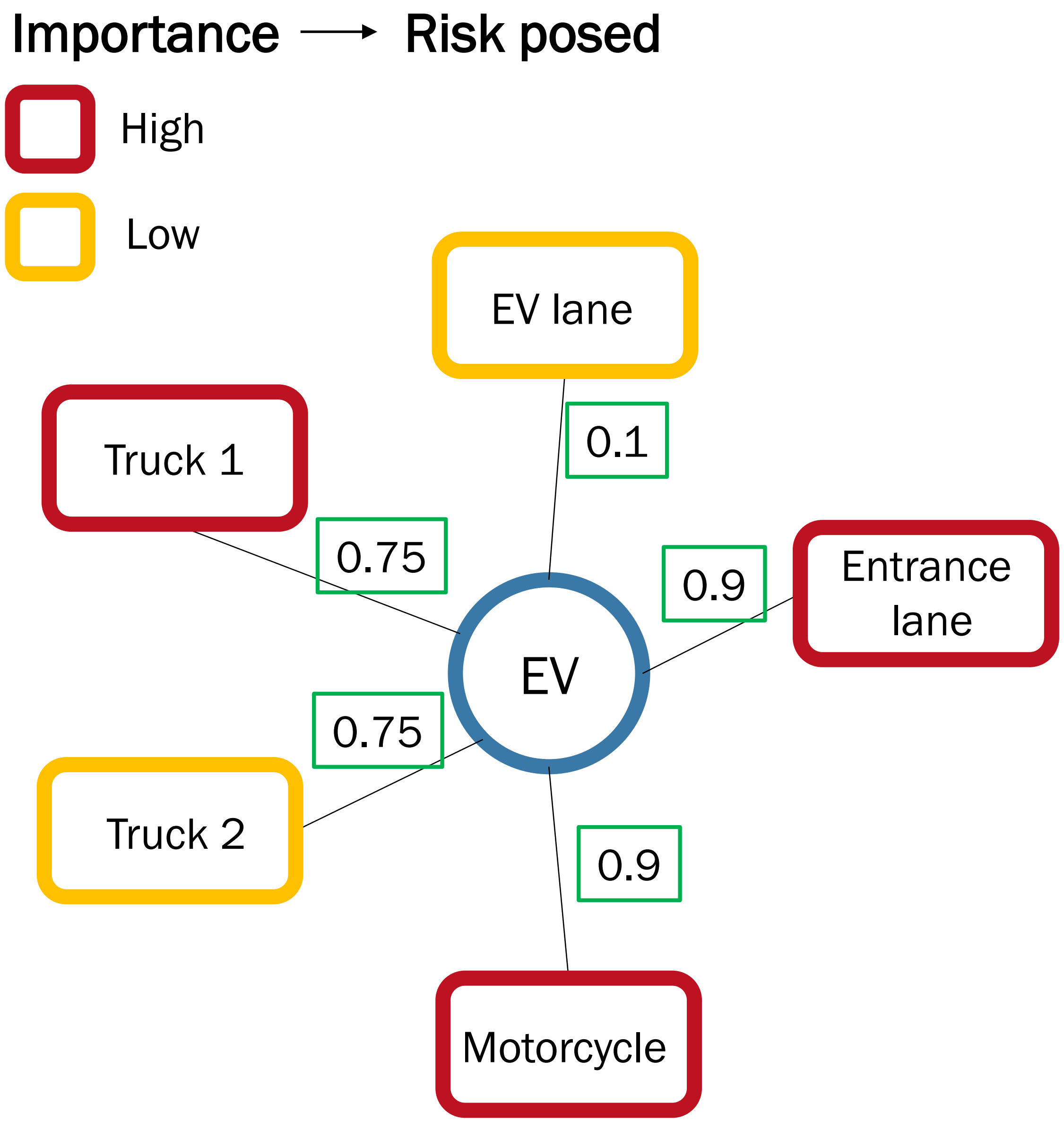
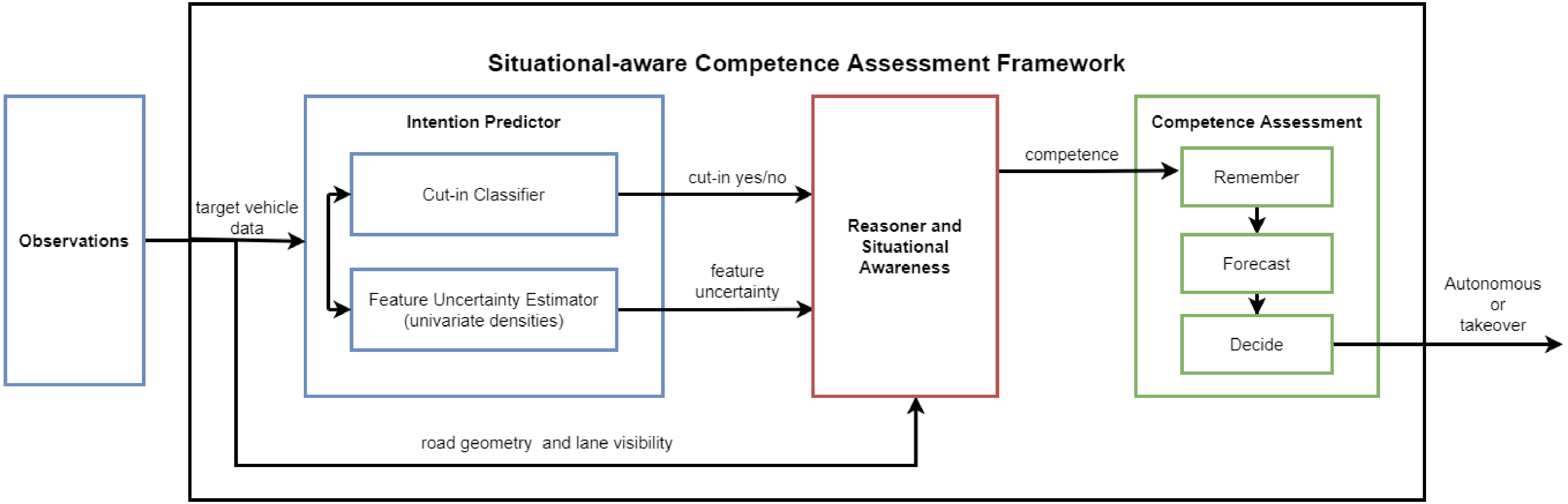


FRAMEWORK
REASONING





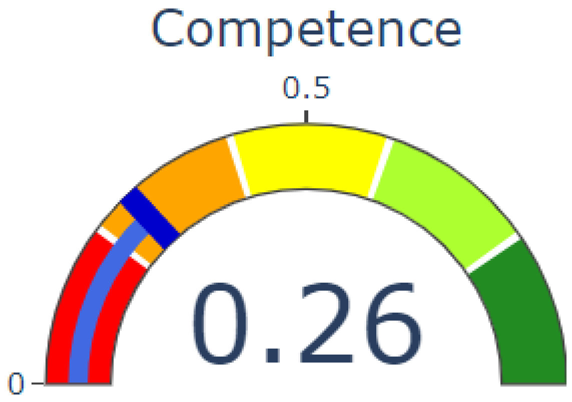
FRAMEWORK
DECISION MAKING



FRAMEWORK

DECISION MAKING

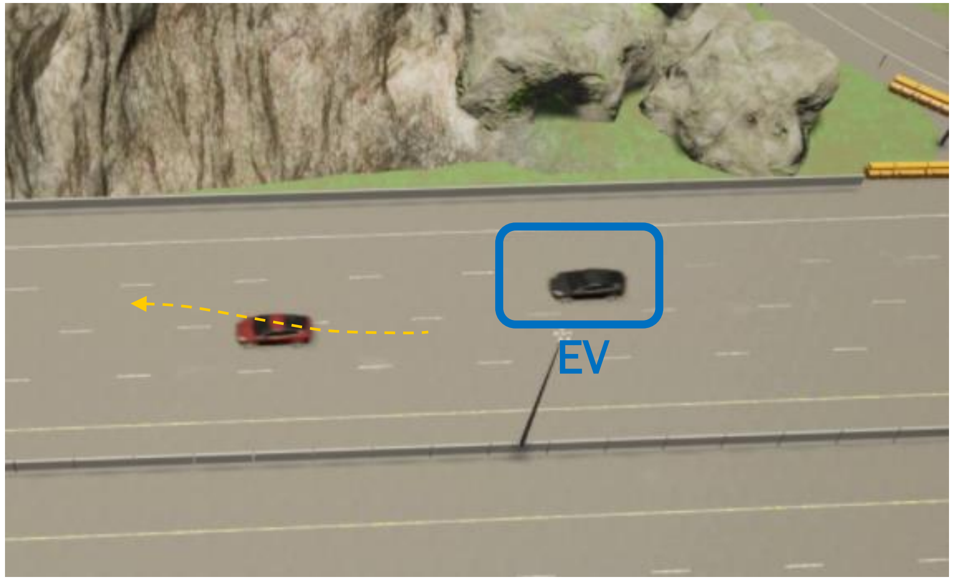
The doubt and importance values are combined via a weighted average to compute a current competence value (embedding). A linear regression algorithm predicts the future competence (forecasting).



Control should be handed over to the human driver when competence < τ

USE CASES

Case	Potential Risk	Reasoner	Competence	Out-of-distribution* measure	Decision $\tau = 0.7$
1	Low	not present	-	0.57	takeover
2	Low	present	0.84	0.57	AD mode



- **Without** the Reasoner, the competence is represented by the out-of-distribution measure that depends on the Feature Uncertainty. Our approach suggests to hand the control over to the driver.
- **With** the Reasoner, the situation is evaluated and the competence results higher than the feature uncertainty.

* 1 – Feature Uncertainty

CONCLUSION

- Novel **Hybrid-AI** framework for the safe application of AI functions in automated driving.
- The Reasoner enhances the estimate of the risk.
- Solid starting point for future investigation of situational awareness.

REFERENCES

[1] Guo, C.; Pleiss, G.; Sun, Y.; and Weinberger, K. Q. 2017. On calibration of modern neural networks. arXiv preprint arXiv:1706.04599

[2] Meyer-Vitali, A.; Bakker, R.; van Bekkum, M.; Boer, M. d.; Burghouts, G.; Diggelen, J. v.; Dijk, J.; Grappiolo, C.; Greeff, J. d.; Huizing, A.; et al. 2019. Hybrid ai: white paper. Technical report, TNO.

[3] Horn, A. 1951. On sentences which are true of direct unions of algebras. The Journal of Symbolic Logic 16(1): 14–21.

THANK YOU AND DRIVE SAFE!

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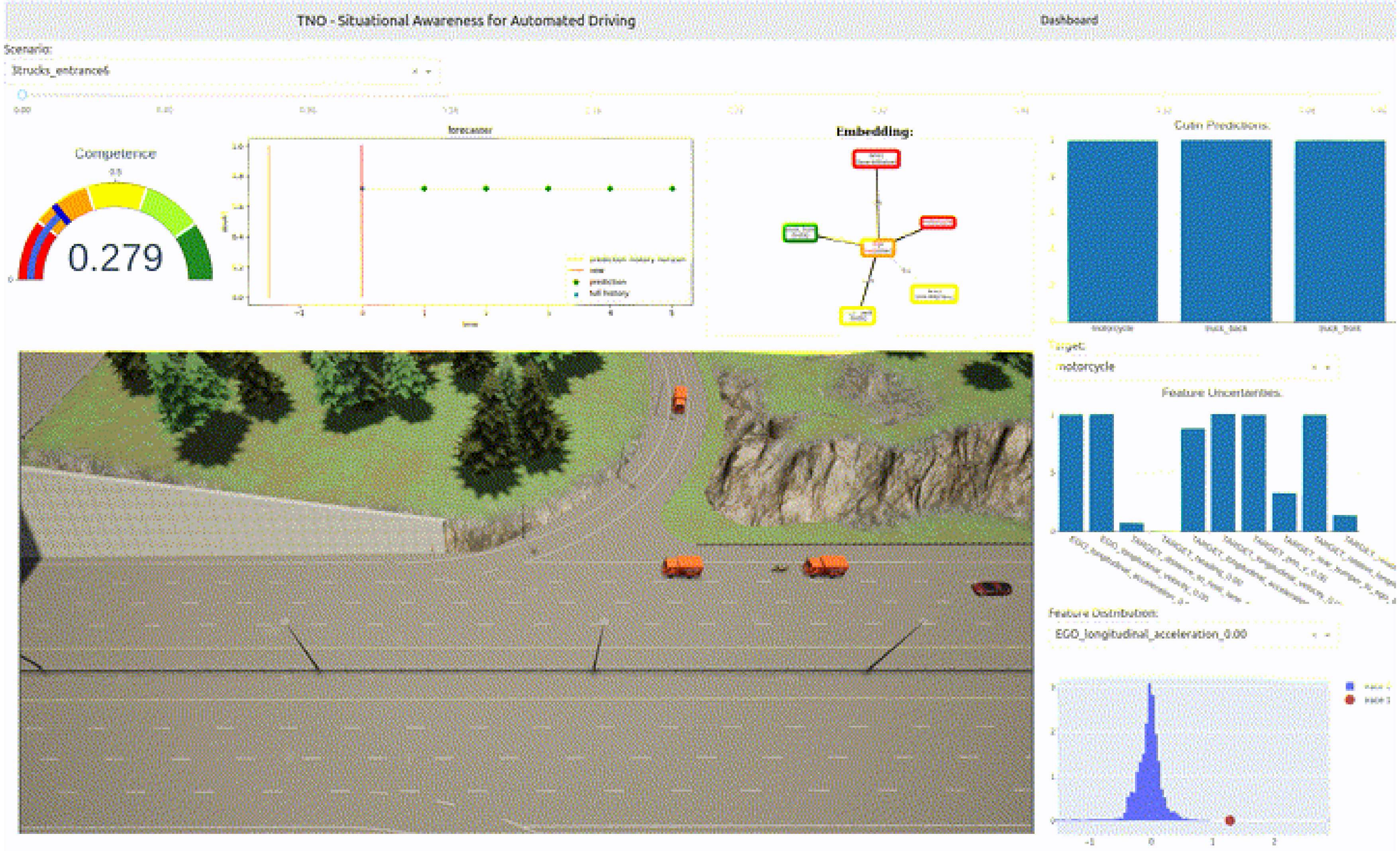
DASHBOARD



TNO - Situational Awareness for Automated Driving
Dashboard
Scenario:
3trucks_entrance6
Competence
0.279
forecaster
Embedding:
Cutin Predictions
Target:
motorcycle
Feature Uncertainties
Feature Distribution:
EGO_longitudinal_acceleration_0.00

LIMITATIONS AND FUTURE WORK

- Increase the number and variety of use cases.
- Graph Neural Networks can be explored to potentially improve the competence assessment.
- Real-life data will be used in the future to move from simulation to real-life.