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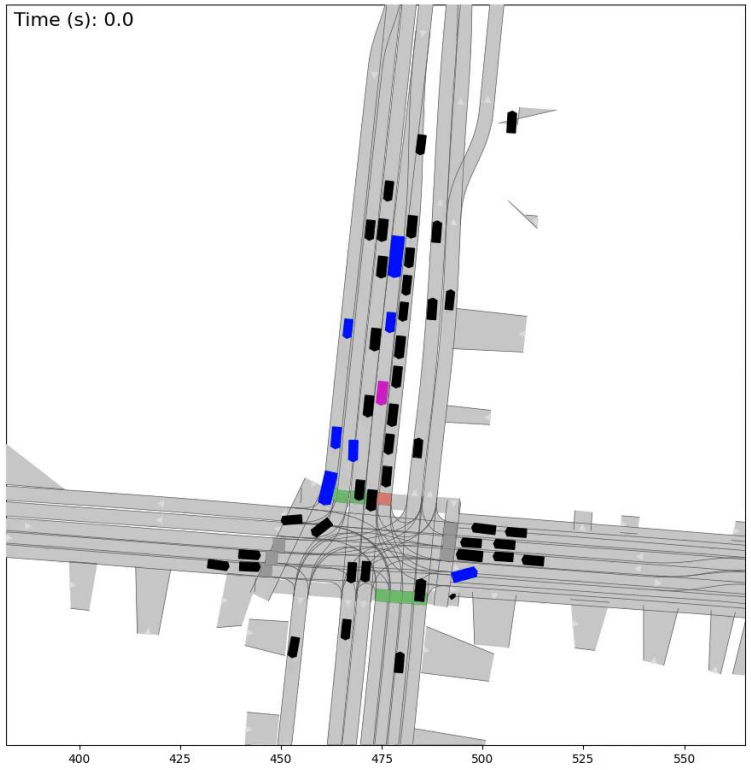
How do you measure the validity of traffic models?

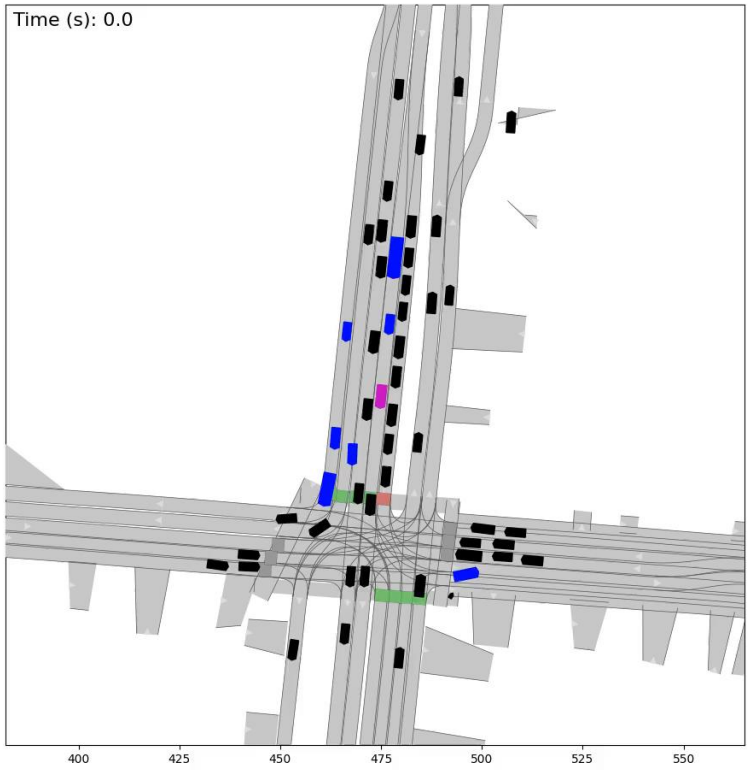
Comparing the driveBOT driver model with state-of-the-art machine learning approaches using public datasets

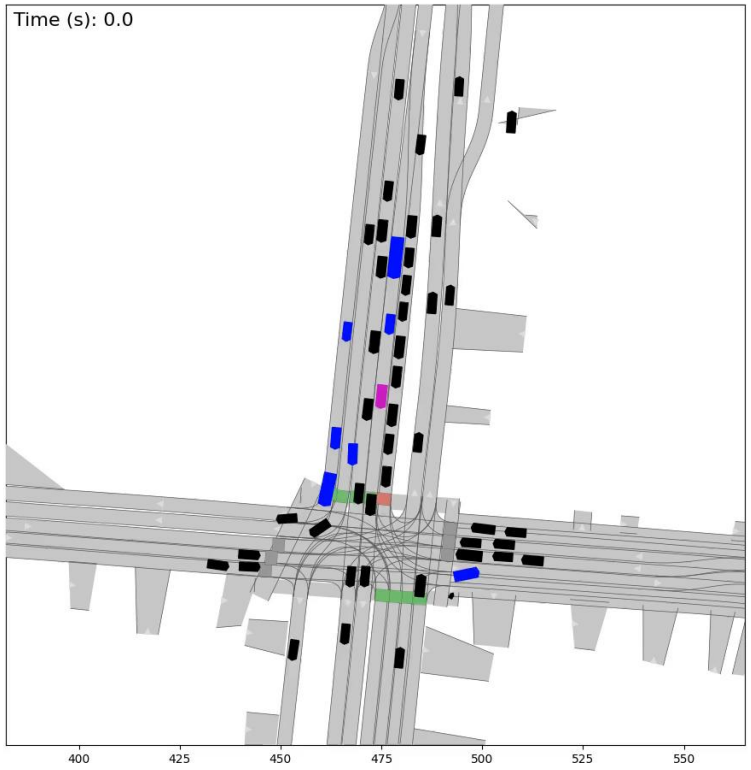
Dr. Lukas Brostek, cogniBIT GmbH

IPG Apply & Innovate 12.09.24

WHICH OF THESE TRAFFIC SCENES IS RECORDED?



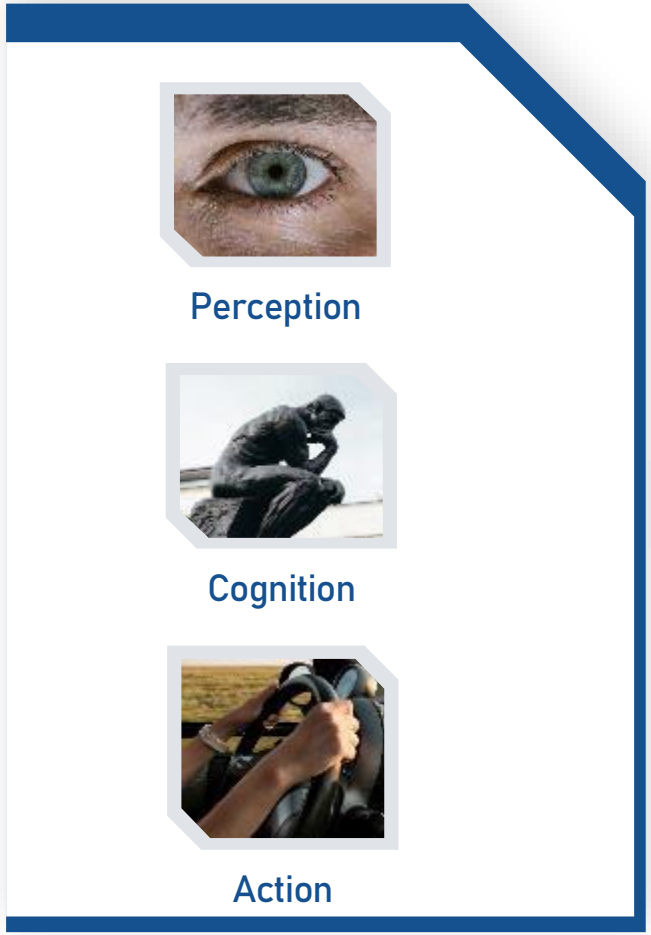




OUTLINE

1. Neuro-cognitive behavior modeling
2. The Waymo Open Sim Agent Challenge
3. Quantifying the validity of traffic models
4. Application in IPG CarMaker

NEURO-COGNITIVE BEHAVIOR MODELING



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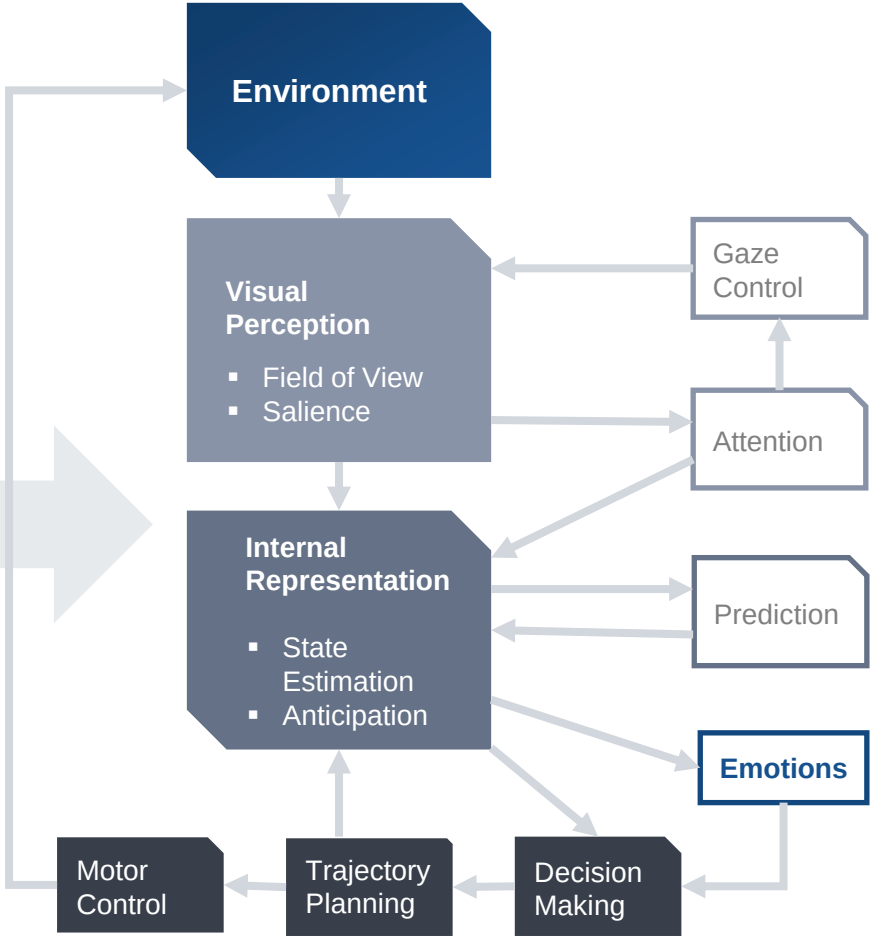
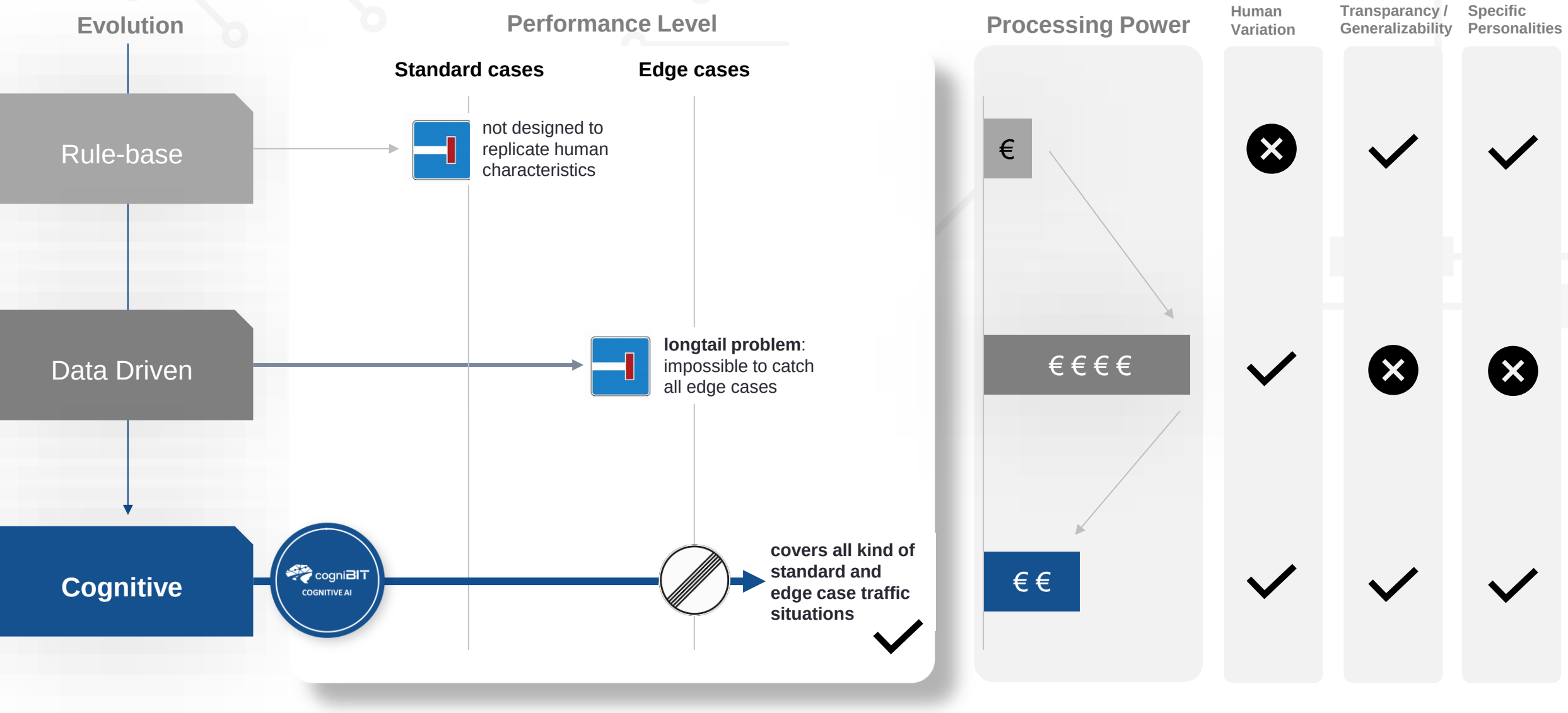
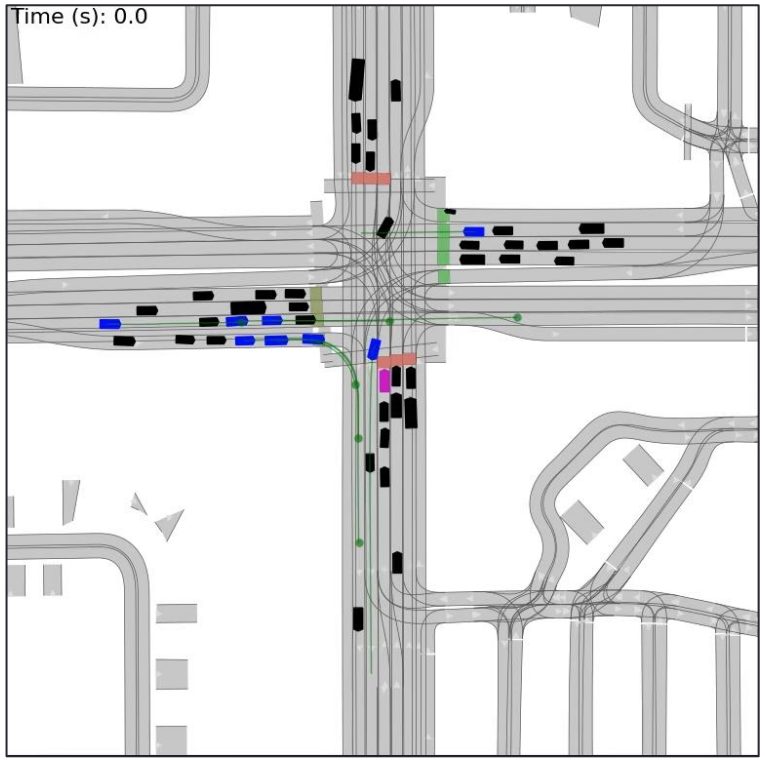
COGNITIVE AI

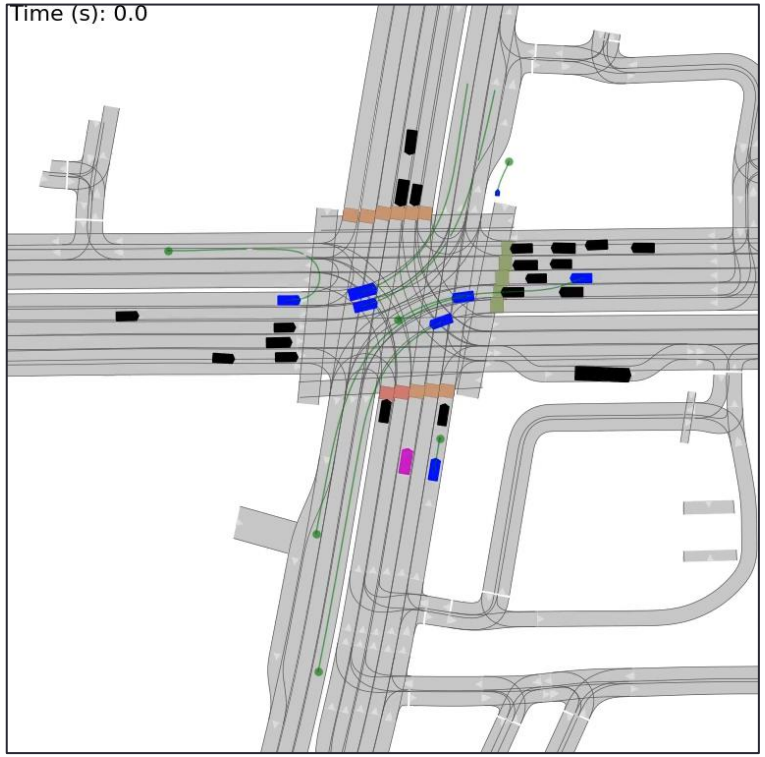


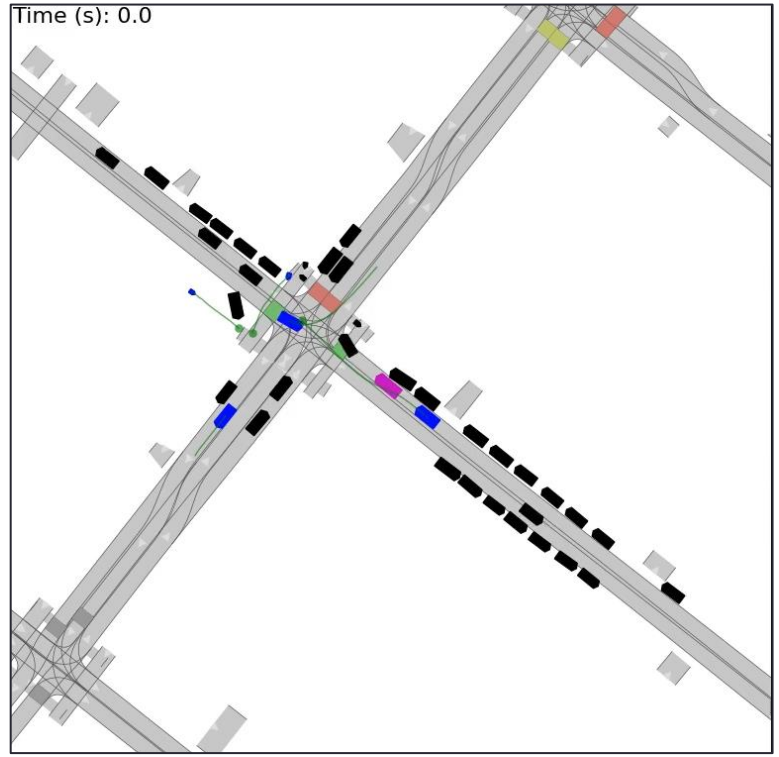
COGNITIVE AI EXCEEDS CONVENTIONAL APPROACHES



THE WAYMO OPEN SIM AGENT CHALLENGE







THE WAYMO OPEN SIM AGENT CHALLENGE

GOAL: WHICH ALGORITHM IS BEST FOR GENERATING REALISTIC TRAFFIC BEHAVIOR ?

Realism Meta Metric

Kinematic Metrics

- Linear speed
- Angular speed
- Linear acceleration
- Angular acceleration

Interactive Metrics

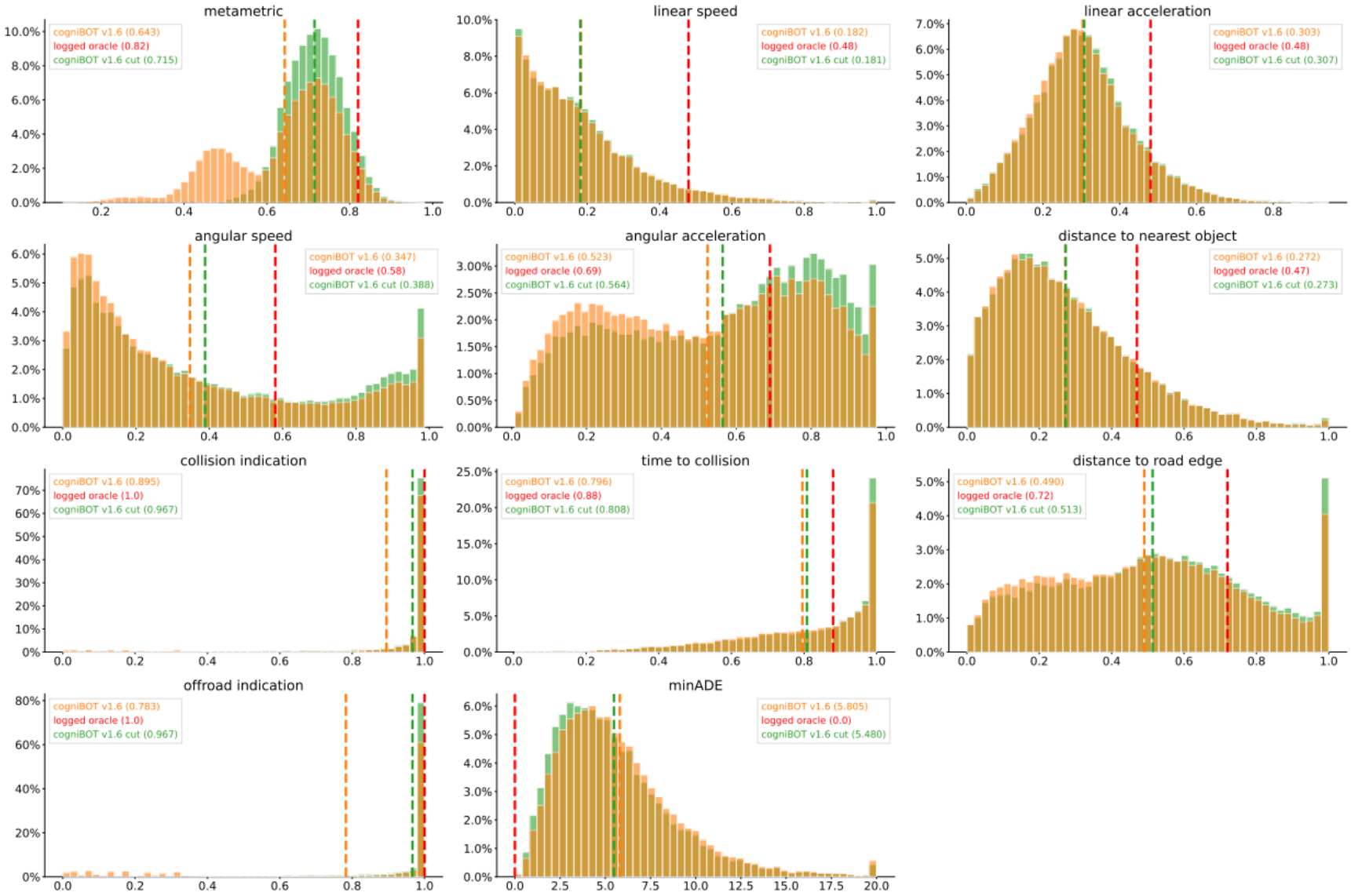
- Collision Indication
- Distance to nearest object
- Time-to-collision

Map-based Metrics

- Offroad indication
- Distance to road edge

THE WAYMO OPEN SIM AGENT CHALLENGE

cogniBOT v1.6



Brostek et al. 2024

THE WAYMO OPEN SIM AGENT CHALLENGE RESULTS 2024

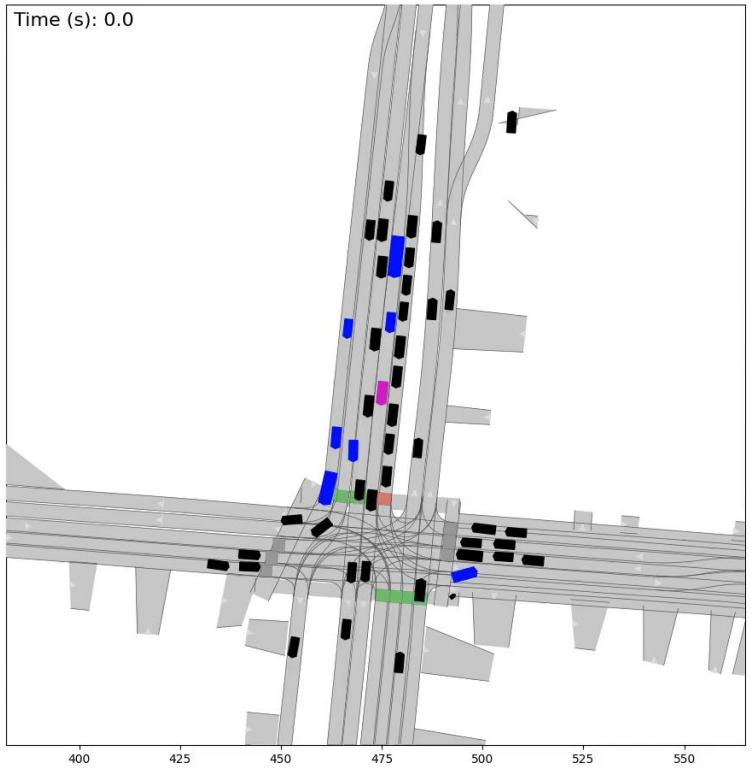
WAYMO

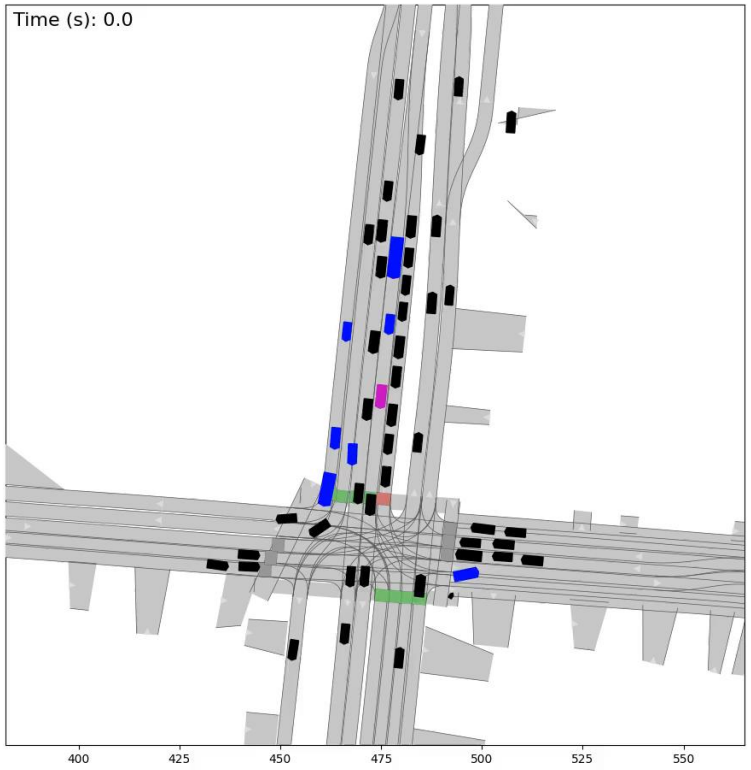
Home | About | Data | Download | Challenges

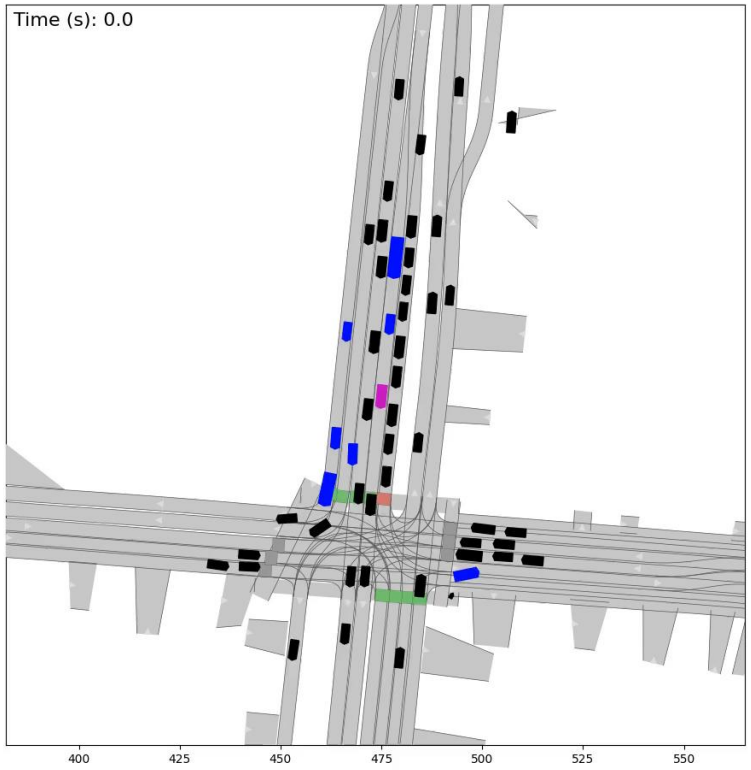
Method Name	Realism Meta metric ↓	Kinematic metrics	Interactive metrics	Map-based metrics	minADE
SMART-large	0.7614	0.4786	0.8066	0.8648	1.3728
KiGRAS	0.7597	0.4691	0.8064	0.8658	1.4384
SMART-tiny	0.7591	0.4759	0.8039	0.8632	1.4062
FDriver-tiny	0.7584	0.4614	0.8069	0.8658	1.4475
SMART	0.7511	0.4445	0.8050	0.8571	1.5447
BehaviorGPT	0.7473	0.4333	0.7997	0.8593	1.4147
GUMP	0.7431	0.4780	0.7887	0.8359	1.6041
model_predictive_submission	0.7417	0.4182	0.7942	0.8591	1.4842
MVTE	0.7302	0.4503	0.7706	0.8381	1.6770
SMART-zeroshot	0.7210	0.4311	0.7806	0.8099	2.5703
VBD	0.7200	0.4169	0.7819	0.8137	1.4743

cogniBOT cut v1.6 0.715

WHICH OF THESE TRAFFIC SCENES IS RECORDED?







recorded traffic scene

simulated (Realism Meta Metric = 0.56)

QUANTIFYING THE VALIDITY OF TRAFFIC MODELS

FINDING THE RIGHT MEASURE

Realism Meta Metric

Kinematic Metrics

- Linear speed
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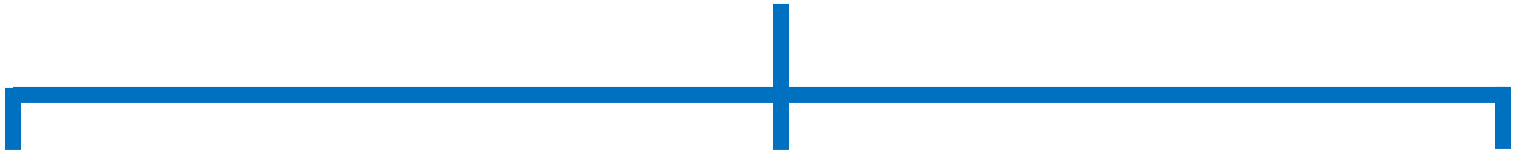
Most of the metrics measure the degree of **reproduction**, not **‚realism‘** of the realization!

QUANTIFYING THE VALIDITY OF TRAFFIC MODELS
FINDING THE RIGHT MEASURE

‚New‘ Realism Meta Metric



Compliance Metrics

- (Heavy) violation of traffic rules

Interactive Metrics

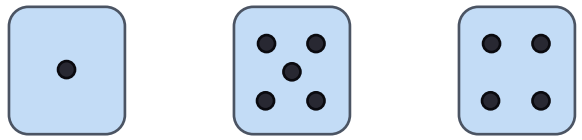
- Collision Indication

Map-based Metrics

- Offroad indication

QUANTIFYING THE VALIDITY OF TRAFFIC MODELS

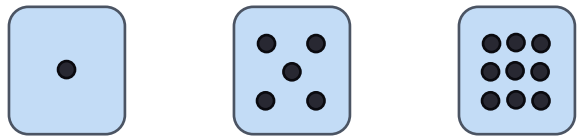
THE RECORDED TRAFFIC SCENE REPRESENTS ONE REALIZATION OF A RANDOM PROCESS



One valid realization for the random process ‚gaming dice‘

QUANTIFYING THE VALIDITY OF TRAFFIC MODELS

THE RECORDED TRAFFIC SCENE REPRESENTS ONE REALIZATION OF A RANDOM PROCESS



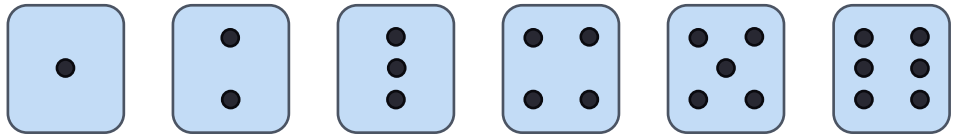
Invalid realization for the
random process ‚gaming dice‘

Single realizations can falsify the model.
But not verify it.

QUANTIFYING THE VALIDITY OF TRAFFIC MODELS

COMPARE DISTRIBUTIONS INSTEAD OF SINGLE REALIZATIONS

Occurence of

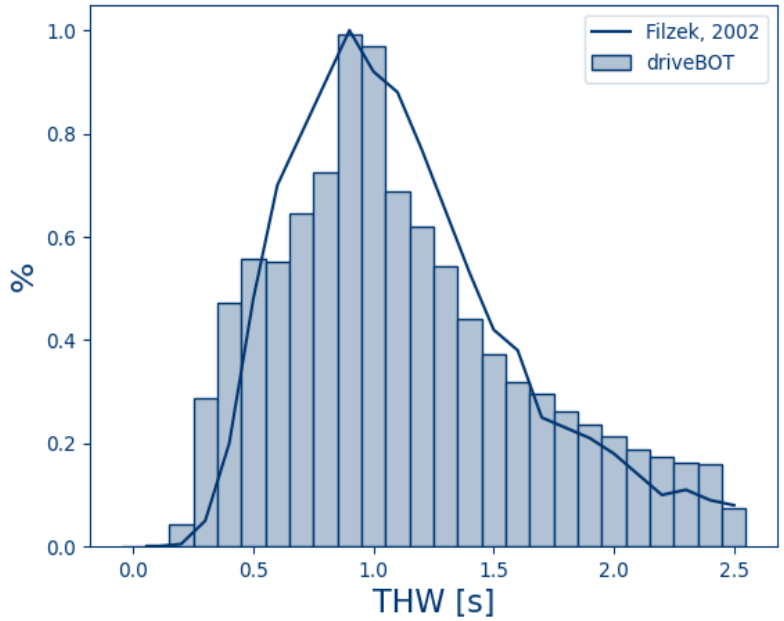


17% 17% 17% 17% 17% 17%

No statistical significant difference between model and real game dice

QUANTIFYING THE VALIDITY OF TRAFFIC MODELS

COMPARE DISTRIBUTIONS INSTEAD OF SINGLE REALIZATIONS



Real-world data of time-headway distribution on German Autobahn (Filzek, 2002, black line) closely resembles simulated data from a highway scenario of our driveBOT

QUANTIFYING THE VALIDITY OF TRAFFIC MODELS

COMPARE DISTRIBUTIONS INSTEAD OF SINGLE REALIZATIONS

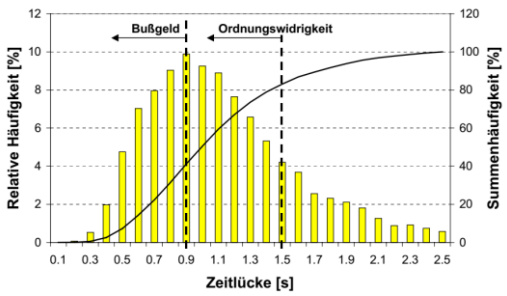
H_0: $\mu_{\text{driveBOT}} = \mu_{\text{real-world data}}$

traffic data

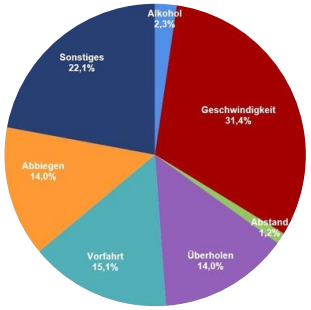
physiological data

continuous

discrete



e.g. distribution of time headway



e.g. statistics of accidents

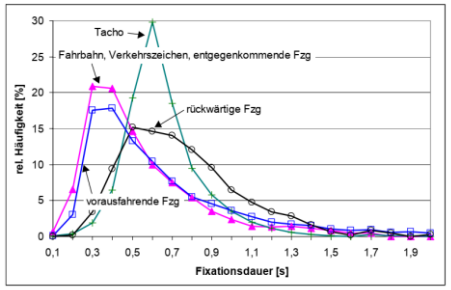


Abbildung 8.4: Häufigkeitsverteilung aller ermittelten Fixationsdauern auf ausgewählte Blickkategorien

e.g. distribution of fixation durations

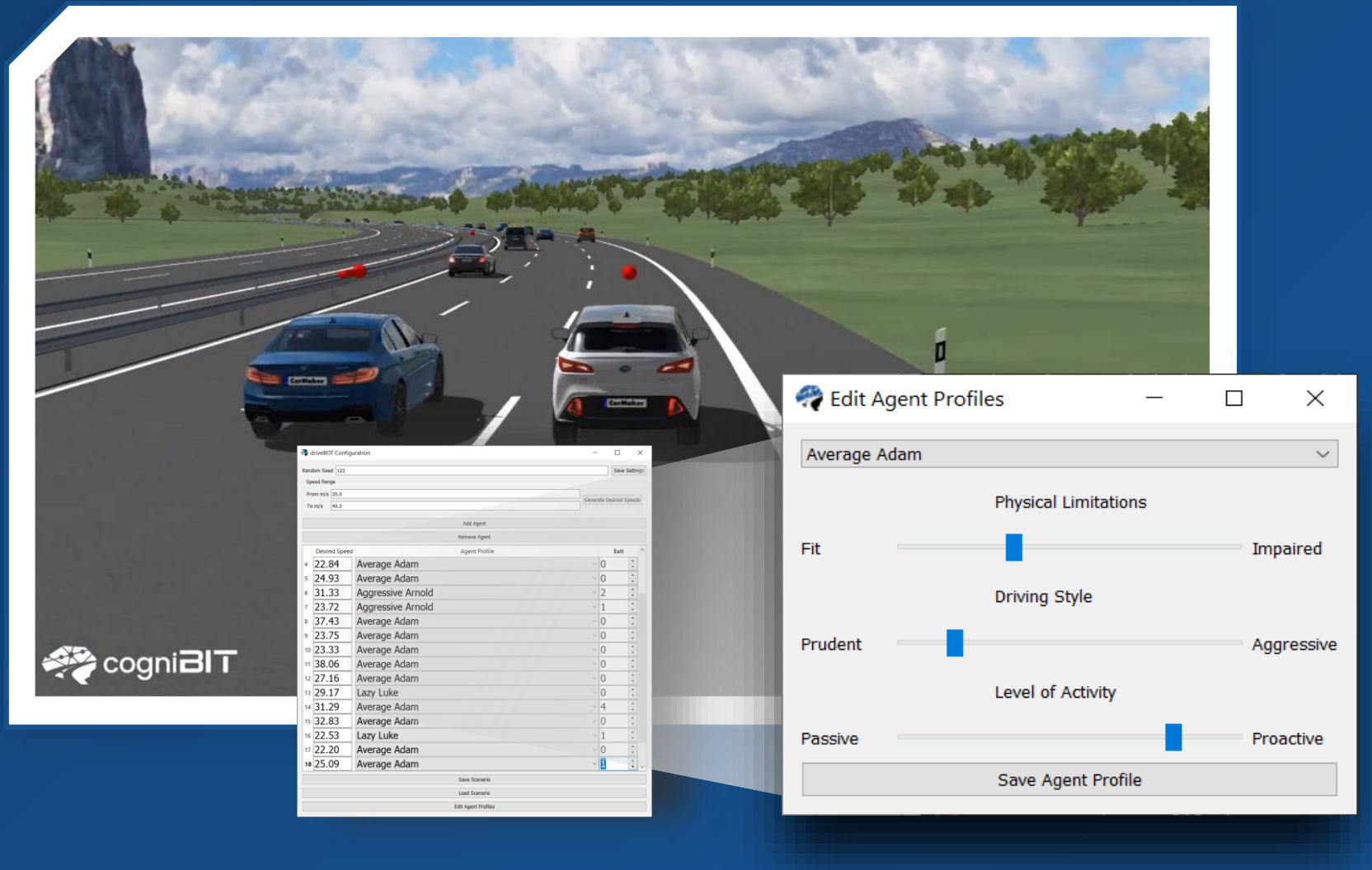
OUR MODELS CAN EASILY BE INTEGRATED INTO IPG CarMaker

driveBOT

driveBOT is the car driver model based on the cogniBOT system architecture.

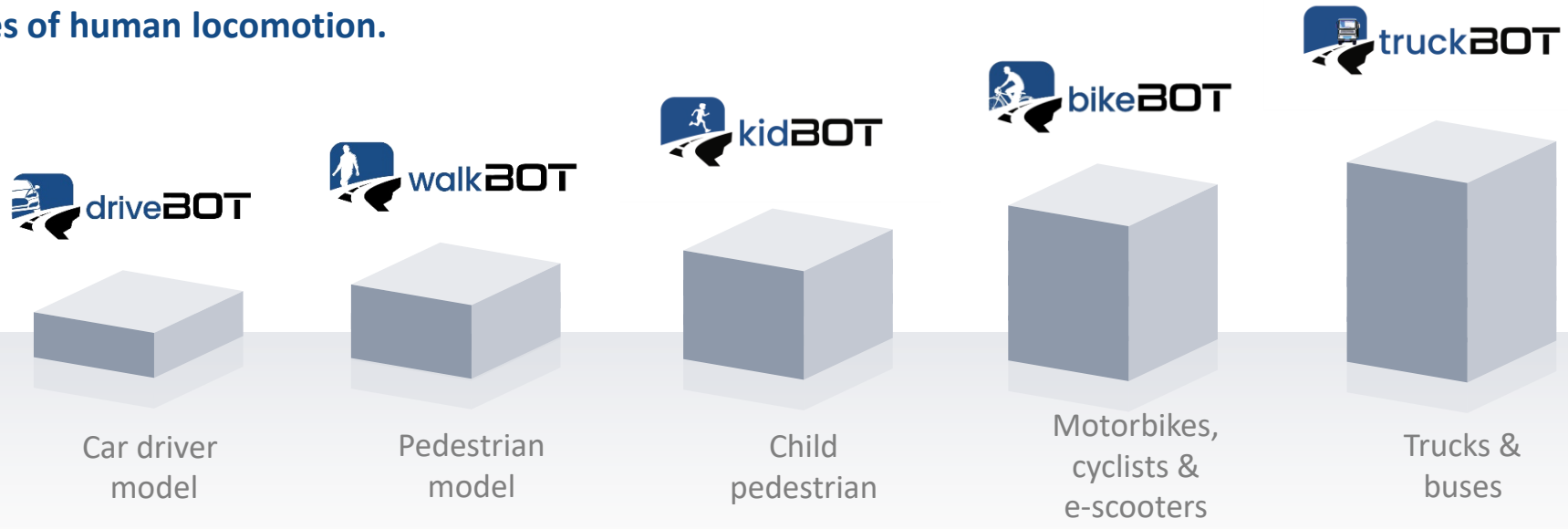
Users can choose pre-configured road user profiles or can create custom personality profiles defining various physiological and psychological parameters such as

- **Physical Limitations**
- **Driving Style**
- **Cautiousness**
- **Level of Activity**
- **Rule Compliance**



OUR PRODUCTS COVER ALL ENVIRONMENTS & MODALITIES

Our cogniBOT system architecture serves as the basis of all cogniBIT products and enables efficient product development to cover all environments and modalities of human locomotion.



cogniBOT

cogniBIT's TECHNOLOGY SUPPORTS ALL STAGES OF THE DEVELOPMENT OF AUTONOMOUS DRIVING & ADVANCED DRIVER ASSISTANCE SYSTEMS

Research

- Training of AI algorithms (e.g. Reinforcement Learning)
- Development of cooperative behavior

Homologation

- Certification
- Approval

Criticality analysis

- Identification of edge & corner cases
- L3 / L4 take-over scenarios
- Human Performance Benchmark

Verification & Validation

- Scenario-based testing
- Closed-loop testing of interactions
- Virtual endurance tests of billions of kilometers

Development

- Level 2 Advanced Driver Assistance Systems
- L3, L4, L5 Autonomous Driving functions
- Integration into Continuous Integration test frameworks

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Human Cognition and Behavior in Traffic

www.cognibit.ai

Lukas.Brostek@cognibit.de

+49 (0) 89 12413996