ZENTRUM FÜR MASCHINELLES LERNEN
KI-LABOR

HOCHSCHULE HEILBRONN

From Simulation to Reality using Reinforcement Learning:

Autonomous Driving and other Applied Research from the Center for Machine Learning at HHN

Center for Machine Learning HHN, Prof. Dr.-Ing. Nicolaj Stache

OUTLINE

- Part 1: Introduction of the „Zentrum für Maschinelles Lernen“
  Overview of research activities
- Part 2: Research Topic:
  Sim-To-Real Transfer for automated driving
- Part 3: Questions, Discussion
  Find topics for collaboration

WELCOME!

Deep-Fake-Video
(Content not available in offline version.)

HEILBRONN UNIV. OF APPLIED SCIENCES (HHN)

> Up-and-coming region

BOSCH WÜRTH Audi LIDL …

+ many „hidden champions“

> HHN: ~ 8600 Students in 4 locations

CENTER FOR MACHINE LEARNING; AI LAB

ZENTRUM FÜR MASCHINELLES LERNEN


Wenn der Computer selbstständig lernt

ZENTRUM FÜR MASCHINELLES LERNEN KI-LABOR


Sprechstunde bei Doktor KI

Interface for companies consulting, awareness raising, entry into AI

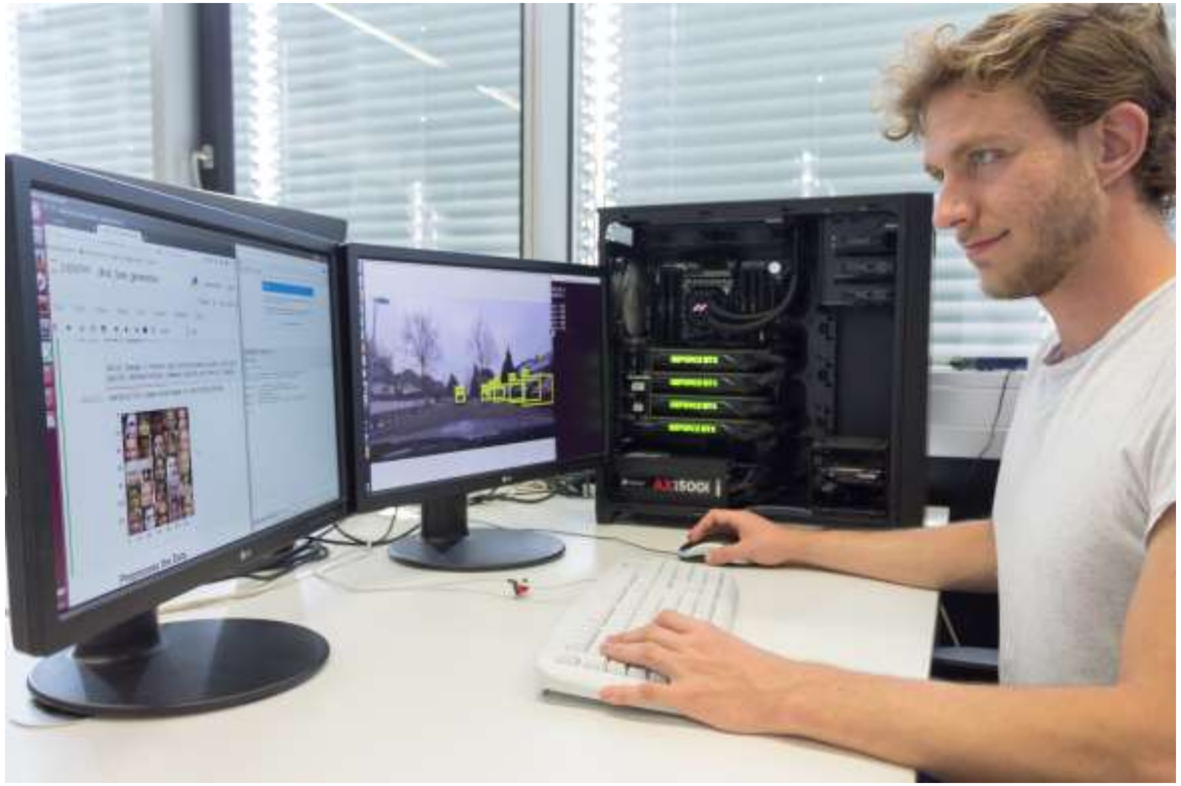
Opening

Services: Trainings, Lecture series
Cooperative research

Continuation as Institute

2018 | 2019 | 2020

MY FOCUS: APPLIED RESEARCH

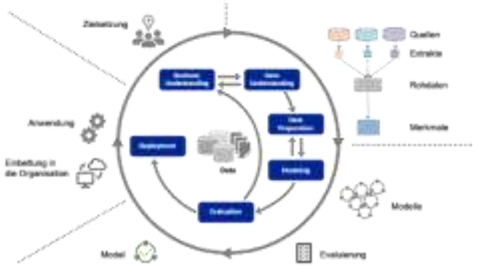


RESEARCH AREAS

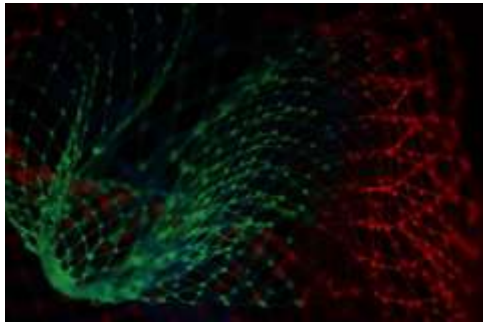
Autonomous Driving

Reinforcement Learning

Industrial Production



Growth Hacking



Health Economics

Neurosciences

Knowledge Management

Web Data Mining

AUTOMATED DRIVING VEHICLE | OVERVIEW

> Research focus:
> Env. Perception and Situation Understanding using AI

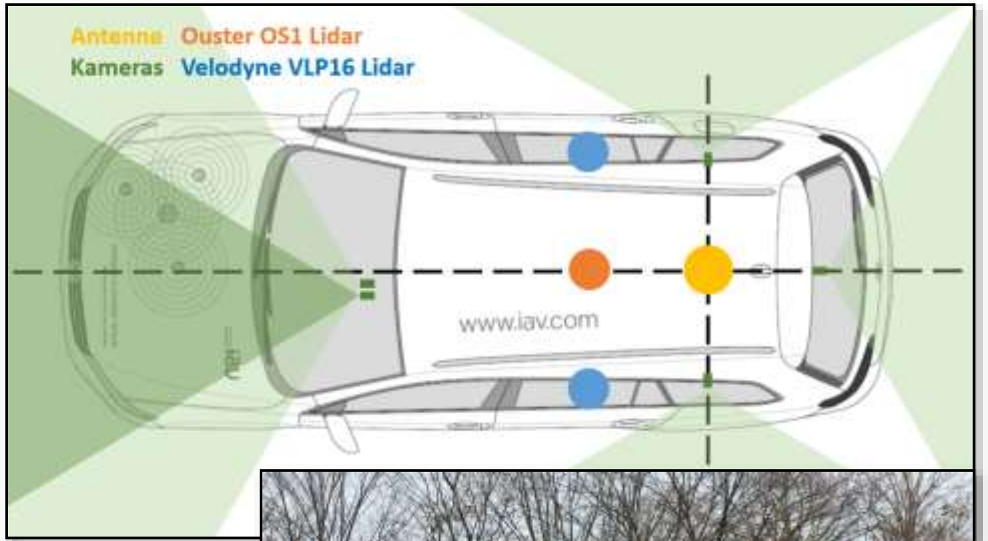
> Vehicle: VW Passat B8 Variant.

- Integrated Highly-Automated-Driving system to completely control the car.
- Eligible to drive on real roads with automated driving turned on.
- Full blown sensor setup.
- Strong computing power in the trunk.

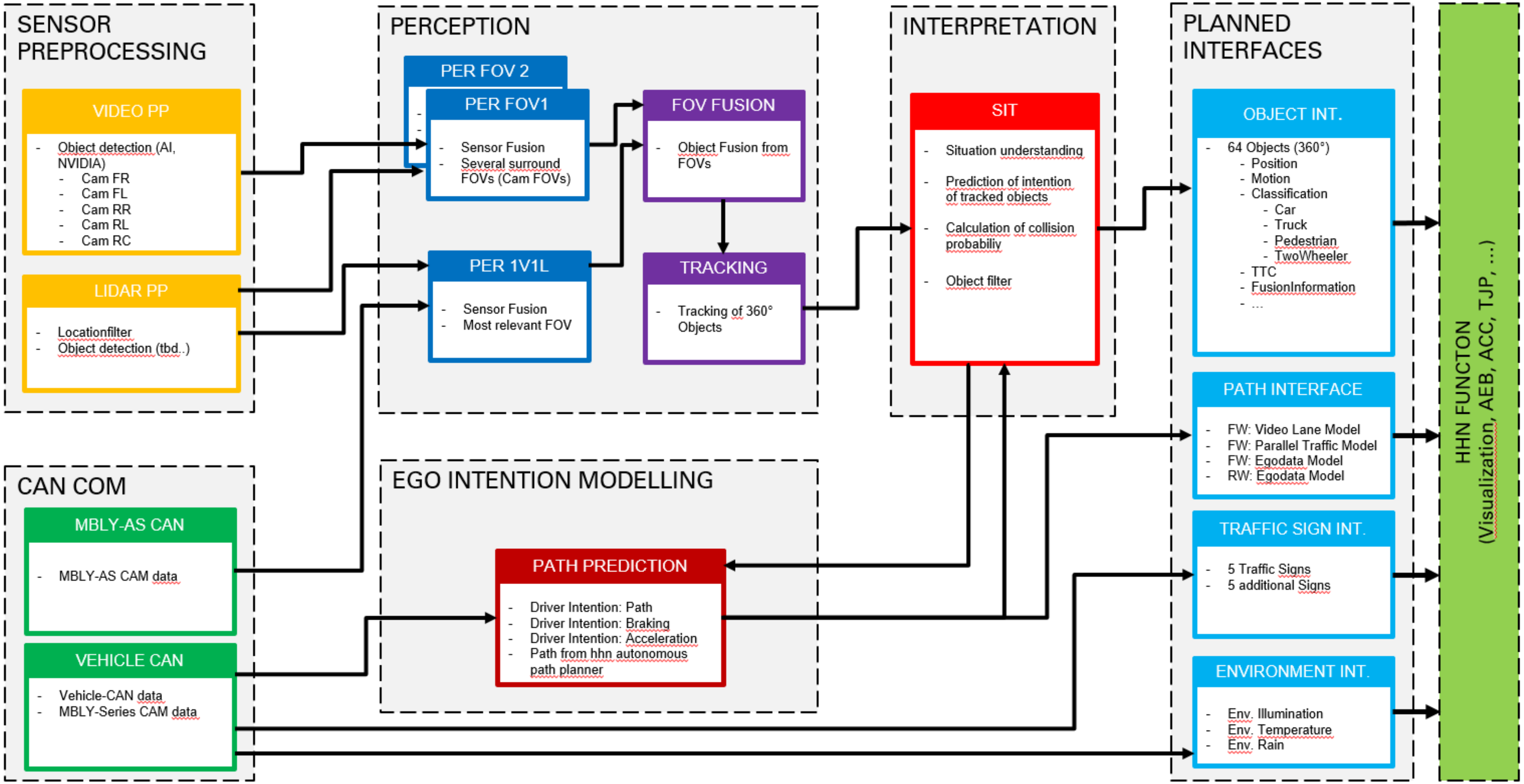
EQUIPMENT / SETUP / SENSORS

> **3 Computer systems**
> **Perception**
  - 3 LiDAR sensors (Laser Scanner)
  - 5 Cameras + Mobileye + internal camera
  - Radar
  - Ultrasonic sensors

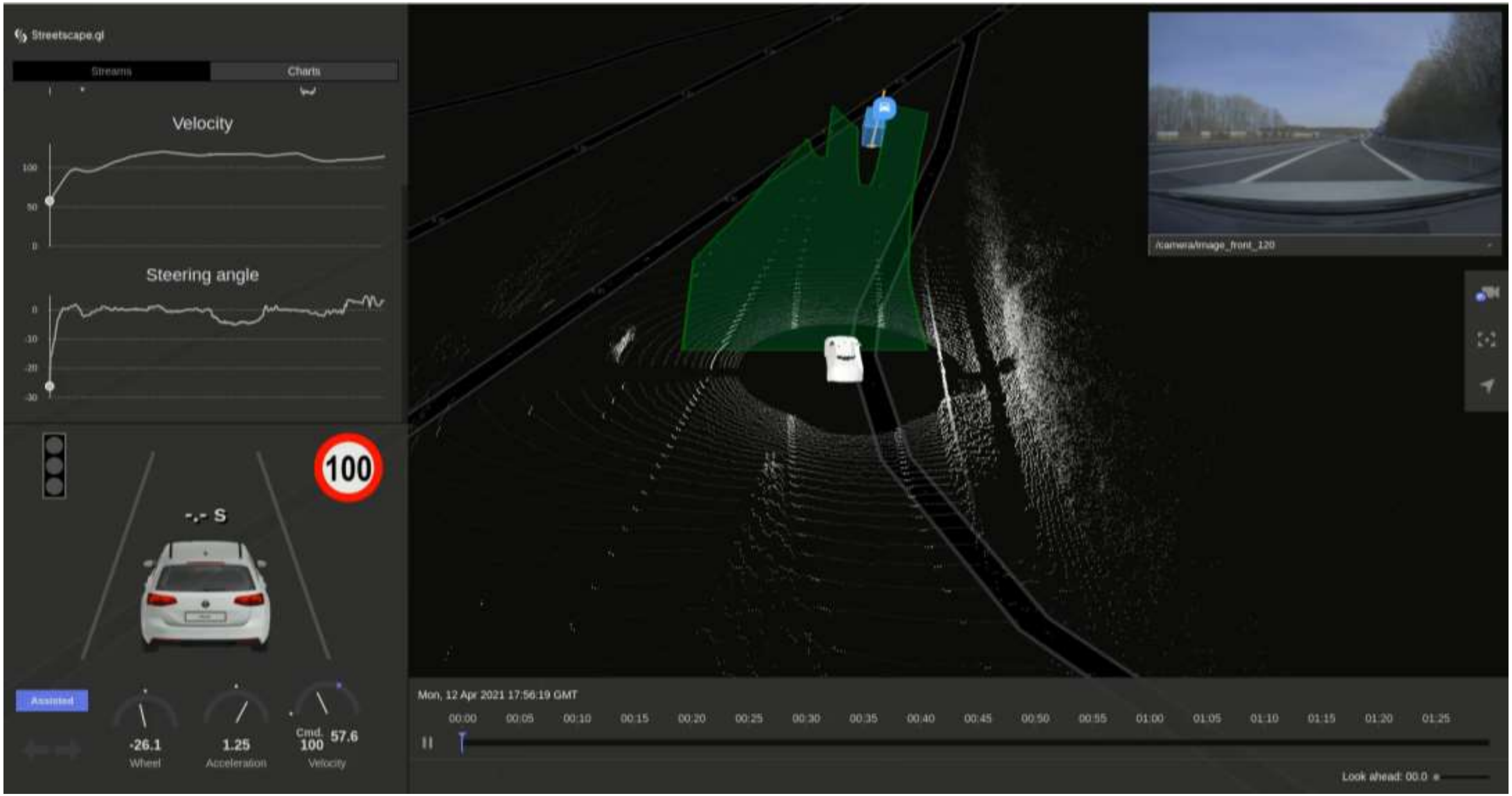
> **Localization**
  - GPS
  - Inertial Measurement Unit
  - Odometry



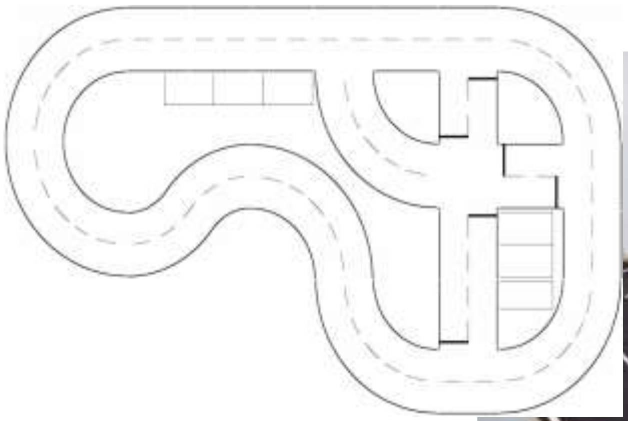
PERCEPTION ARCHITECTURE VW PASSAT

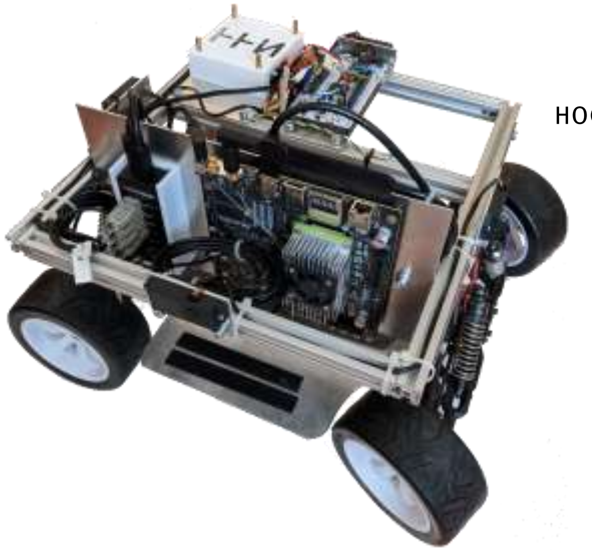


PERCEPTION ARCHITECTURE VW PASSAT



AUTONOMOUS DRIVING ON SCALE 1:8





> Focus: Cooperative driving, new AI approaches, distributed AI

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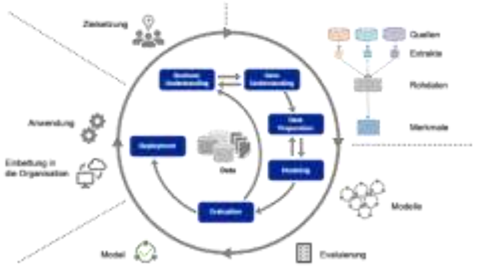
RESEARCH AREAS

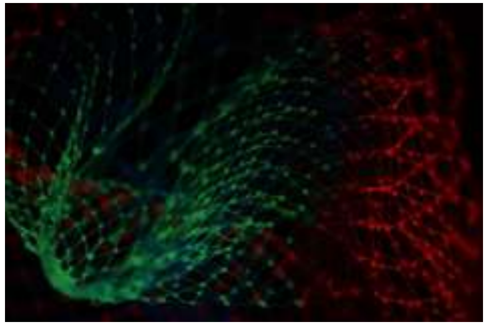
Autonomous Driving

Reinforcement Learning

Industrial Production



Growth Hacking



Health Economics

Neurosciences

Knowledge Management

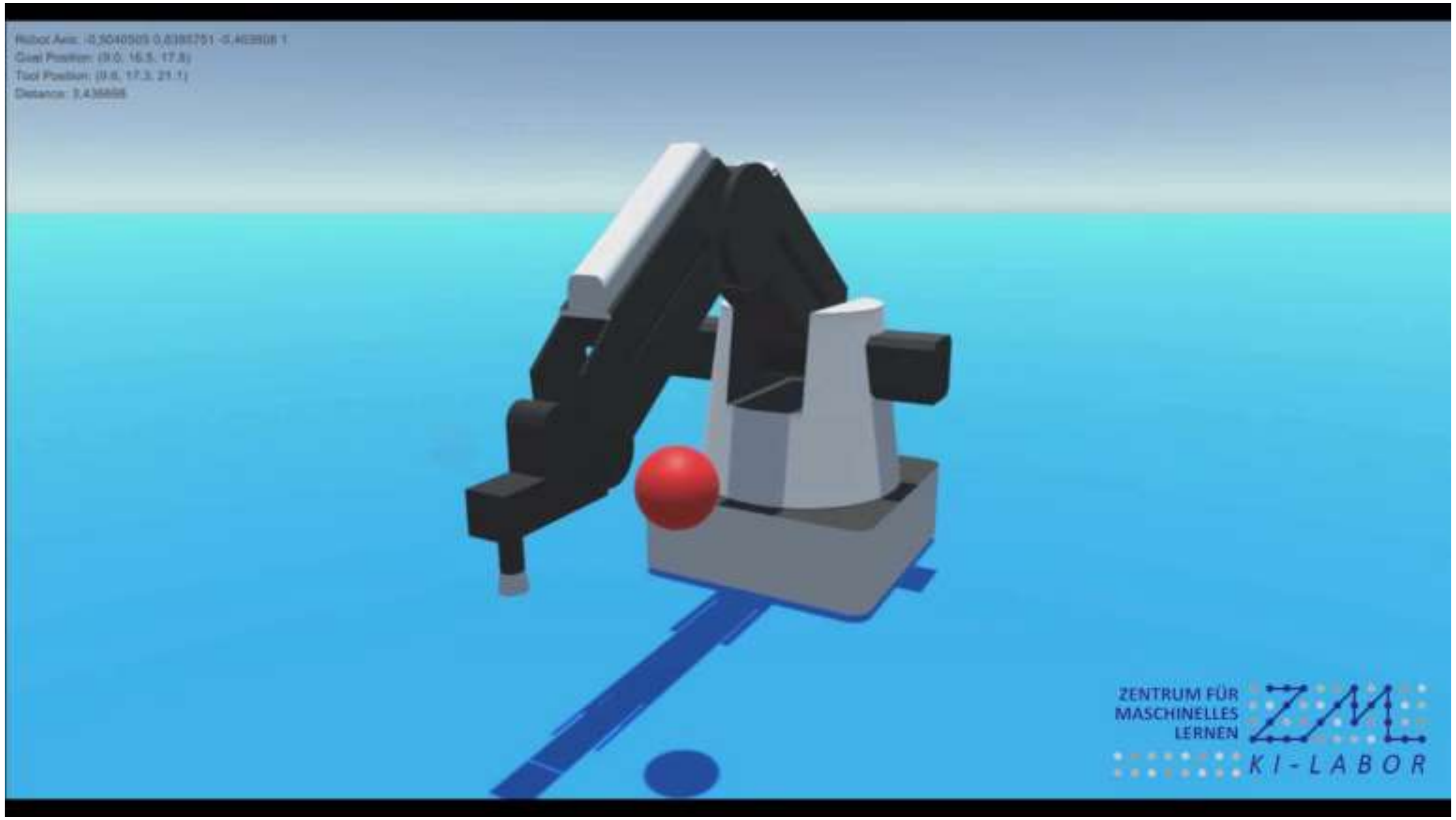
Web Data Mining

AI LEARNS TO DRIVE IN A SIMULATION

RESULT ON A TEST TRACK

RL AIRHOCKEY

RL ROBOT



> Focus: Application of AI in industry (pick and place), research on new AI approaches

RESEARCH AREAS

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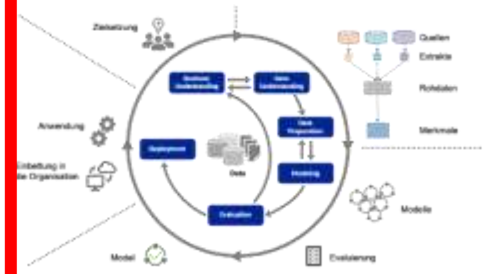
Reinforcement Learning

Industrial Production



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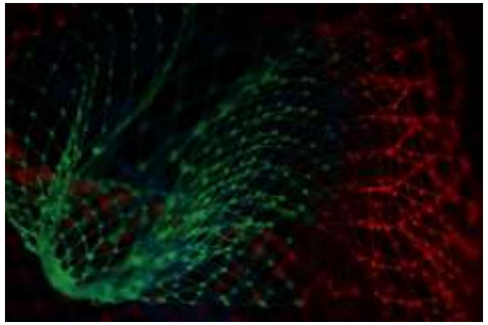

Health Economics

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ZENTRUM FÜR MASCHINELLES LERNEN

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PRODUCTION PLANT MONITORING

OUTLINE

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> Overview of research activities

> Part 2: Research Topic:
> Sim-To-Real Transfer for automated driving

> Part 3: Questions, Discussion
> Find topics for collaboration

AUTOMATED DRIVING VIA RL: SIM VS. REAL

- Over 400 km without fatalities in the simulation
- Half a lap in reality

MOTIVATION

Simulation

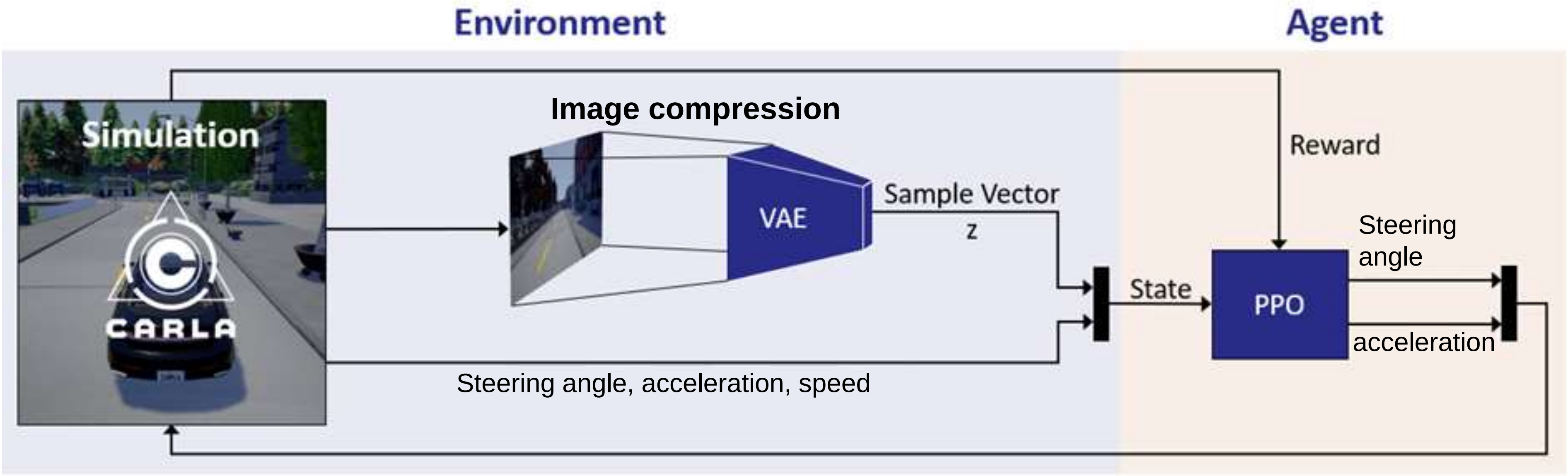
- Infinite amount of training data
- Precise control of environment parameters
- No risk of physical damage
- Reproducibility of tests

Transfer Method

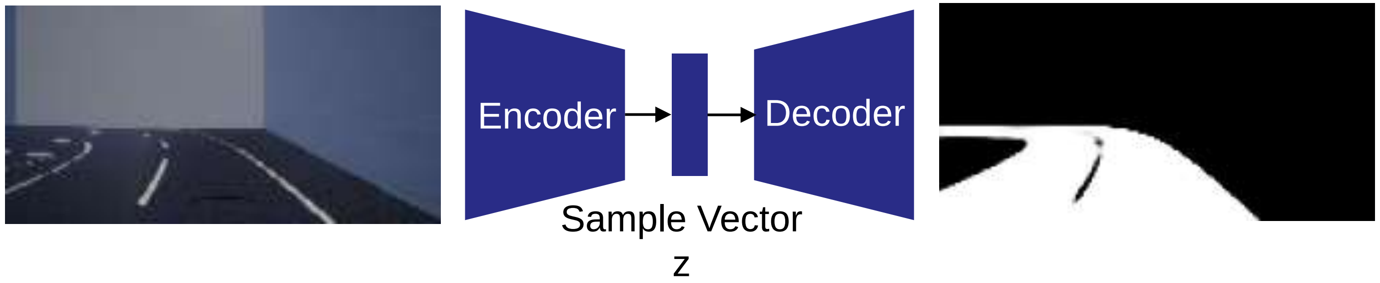
DOMAIN GAP

Reality

BASELINE APPROACH

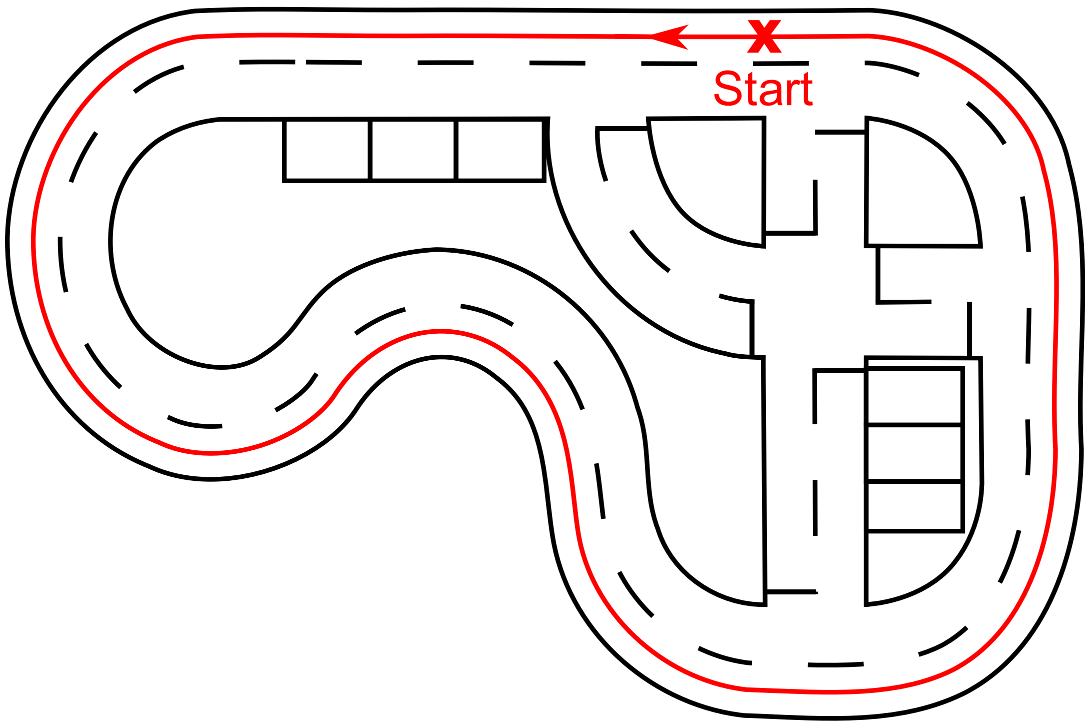


Simplified principle of VAE



GOALS

- 20 laps without mistakes on the real course
- Calm, human-like driving behavior
- As little labeled data as possible
- Robust against lighting changes



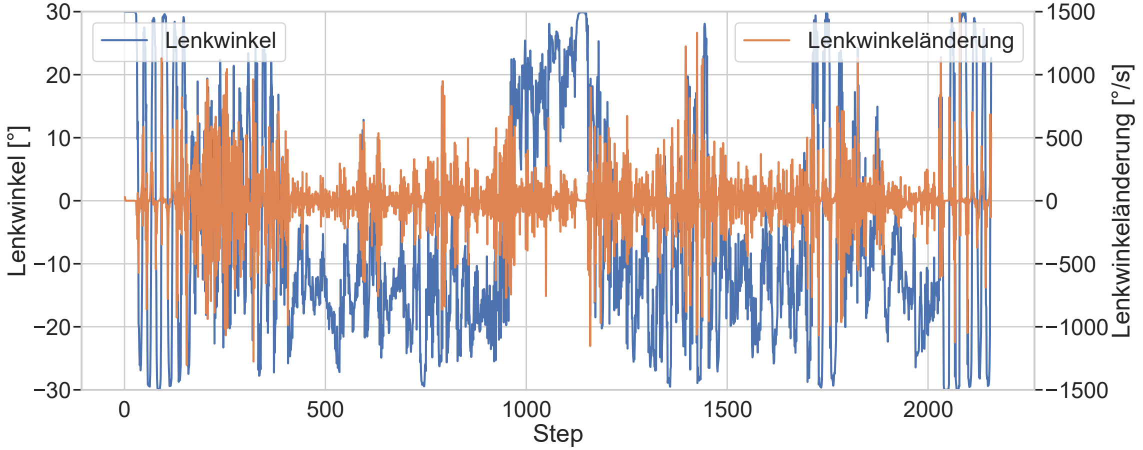
METRICS

Comfort

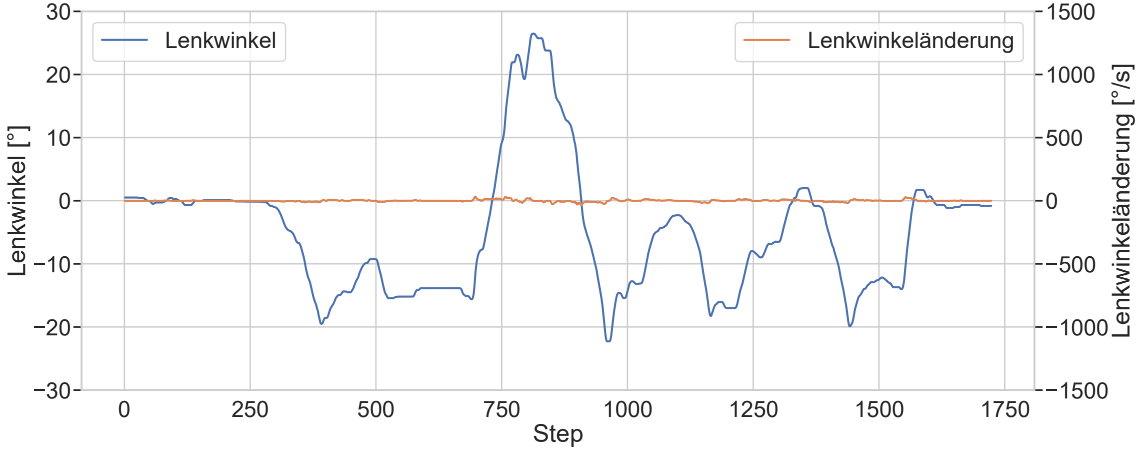
$$\text{Comfort} = \sqrt{\frac{1}{N}\sum_{n=0}^{N} \dot{\alpha}_n^2}$$

> $N = Number\ of\ data\ points$
> $\dot{\alpha} = change\ of\ steering\ angle$

Baseline



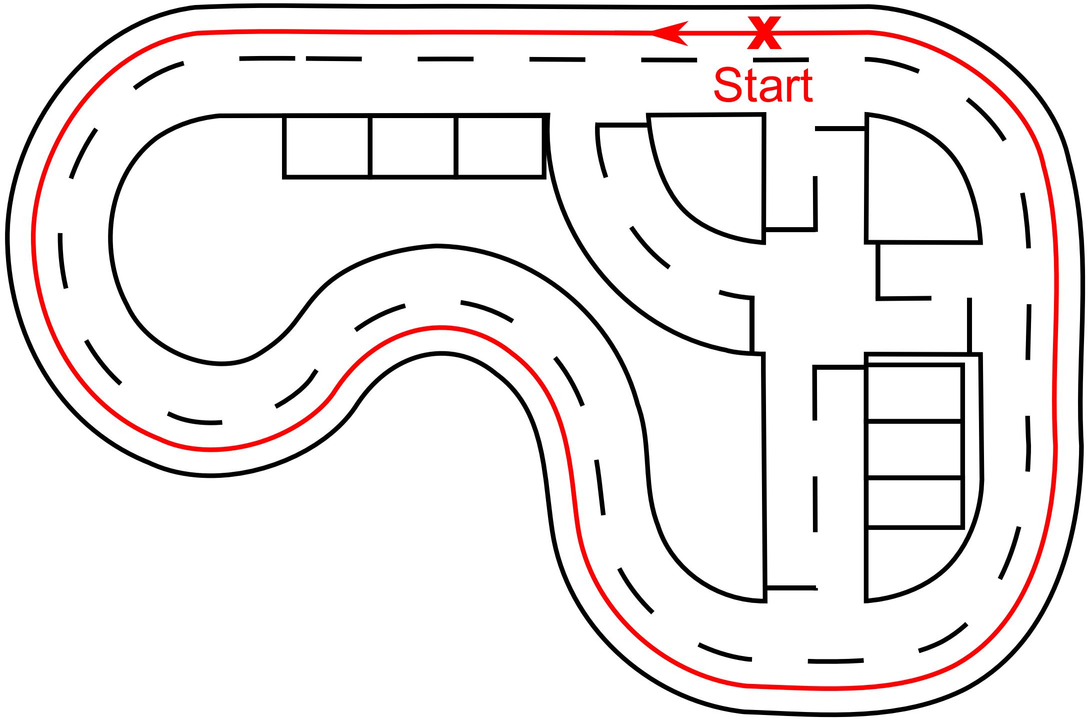
Human



METRICS

Mean Distance Between Failures (MDBF)

$$MDBF = \frac{d}{n_F}$$

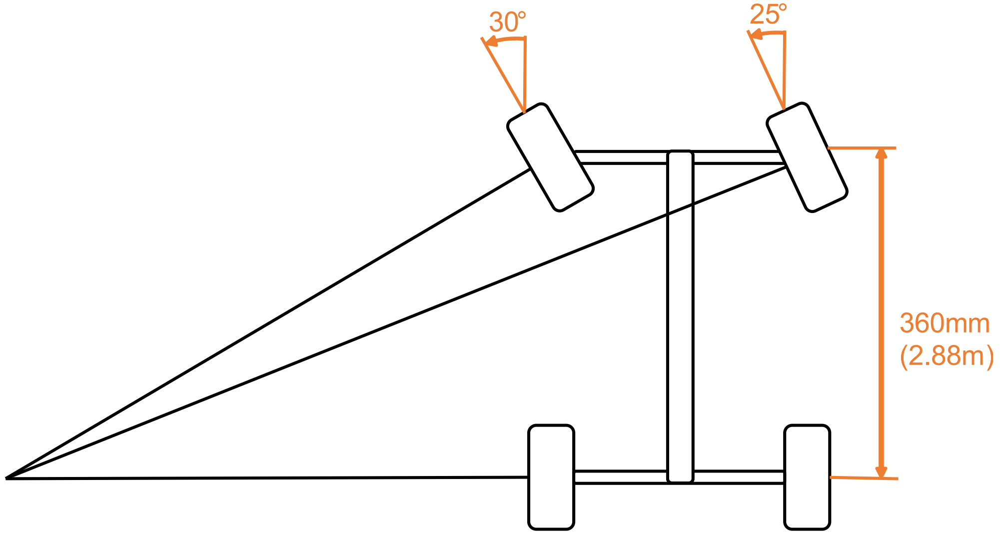


MINIMIZATION OF THE PHYSICAL DOMAIN GAP

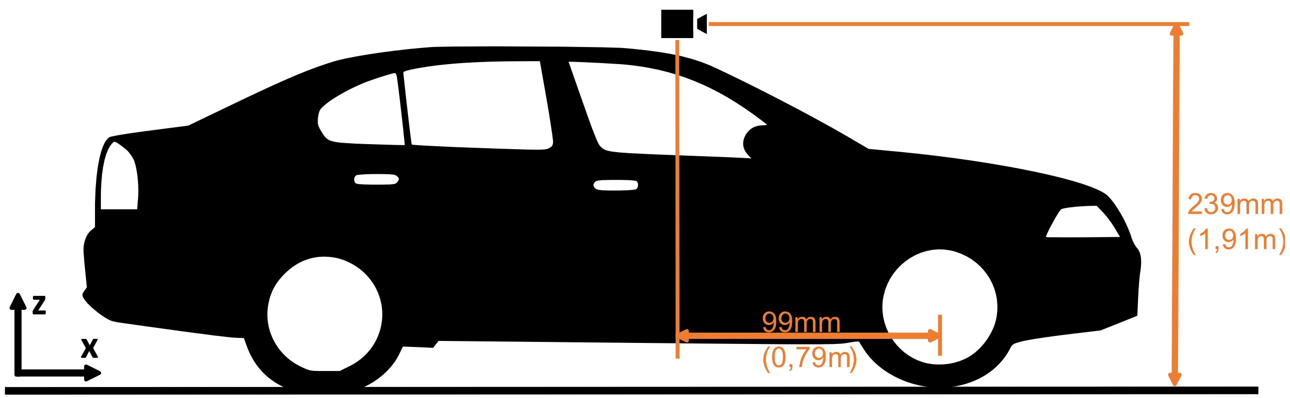
Intrinsic camera parameters

FOV	Width	Height
130°	1280 px	960 px

Wheelbase and steering angle



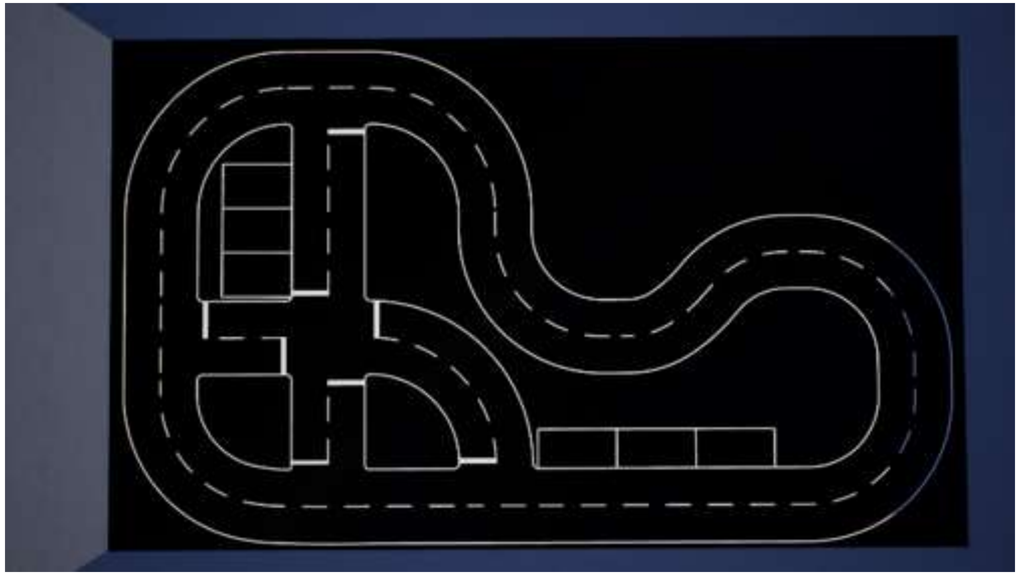
Extrinsic camera parameters



MINIMIZATION OF THE VISUAL DOMAIN GAP

Reality

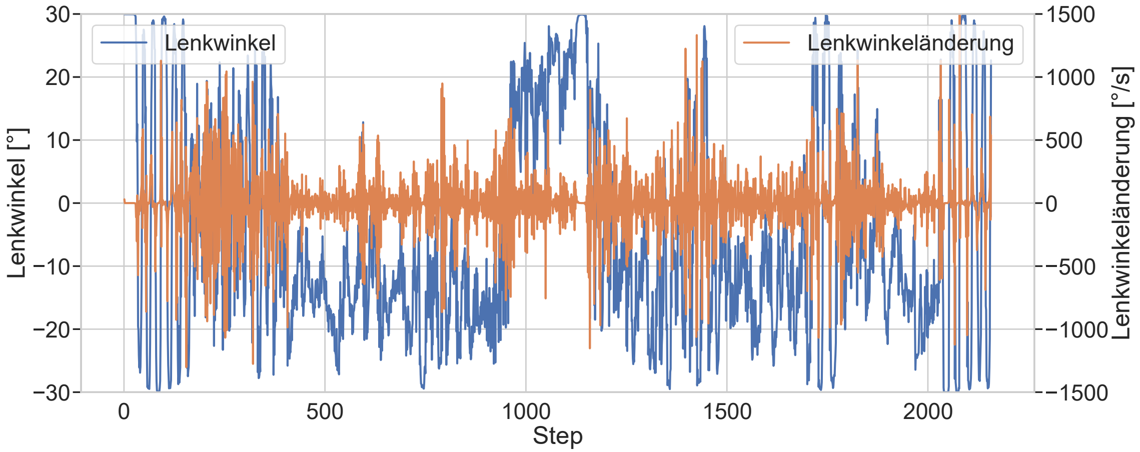
Simulation



ELIMINATION OF UNEVEN DRIVING BEHAVIOR

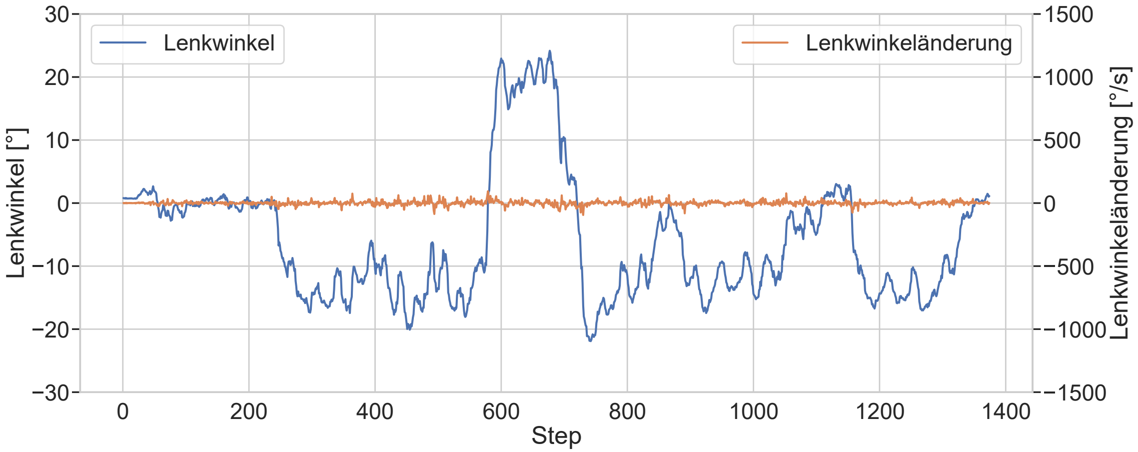
Baseline

$Comfort = 238\,°/s$

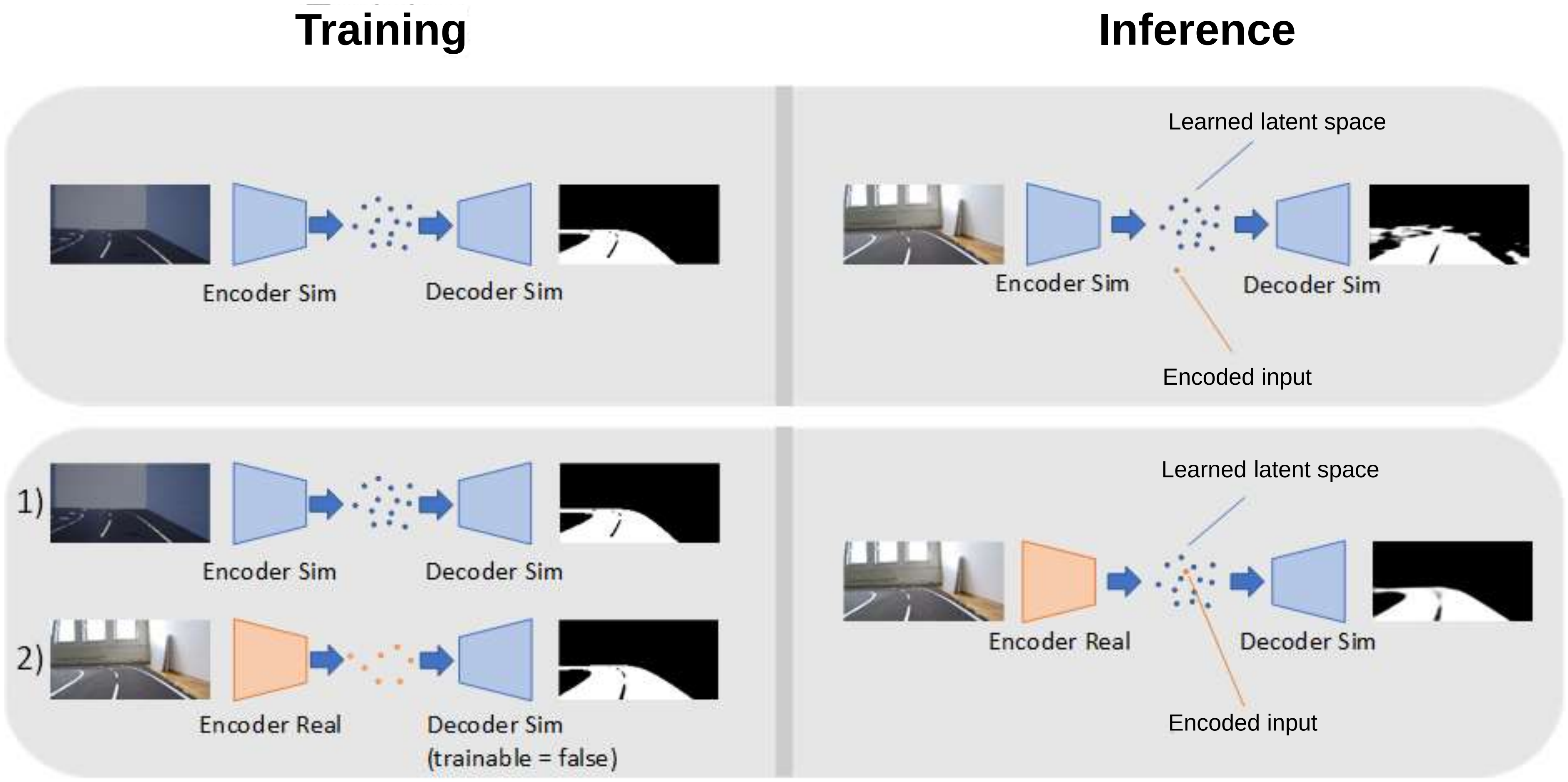


Hyperparameter $\sigma_{init} = 0.1$ of Policy Gradient Algorithm

$Comfort = 29\,°/s$



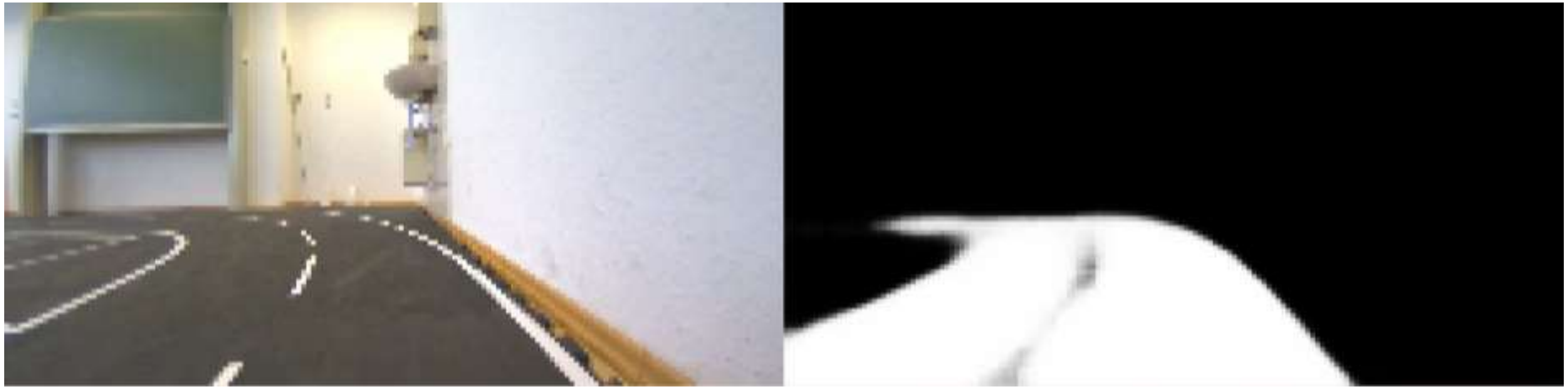
DOMAIN ADAPTATION (DA)



DOMAIN ADAPTATION (DA)

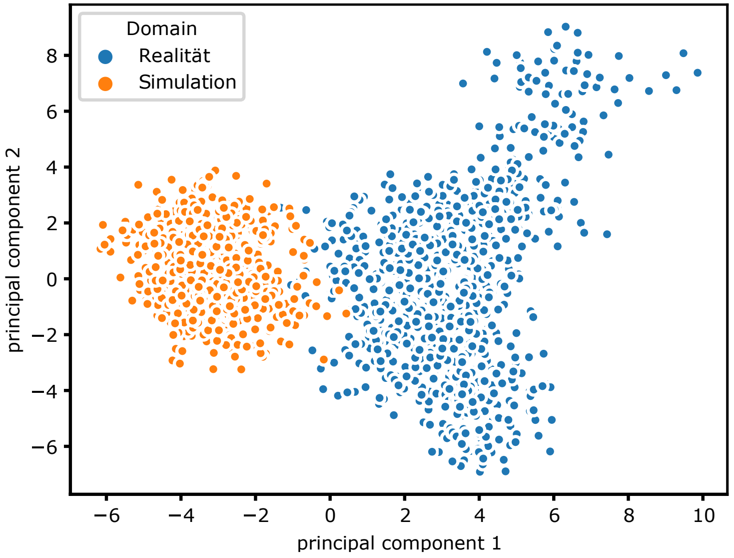
Baseline

Domain Adaptation



DOMAIN ADAPTATION (DA)

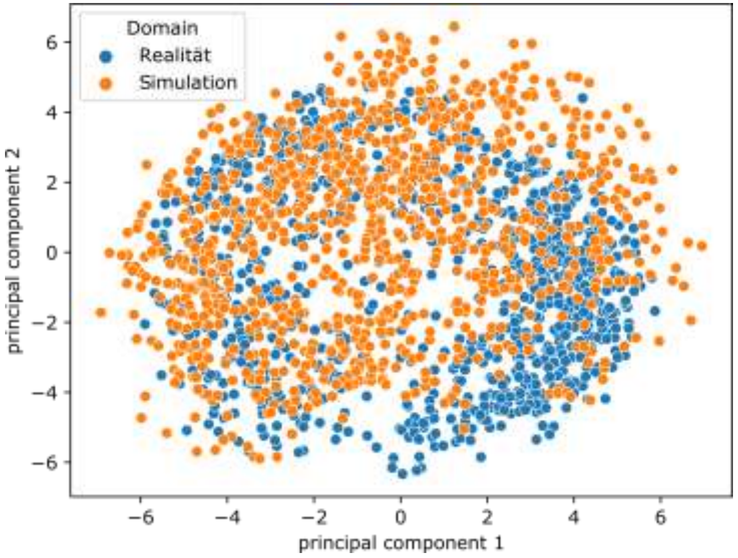
Baseline



$$MDBF = 4{,}07\ m$$

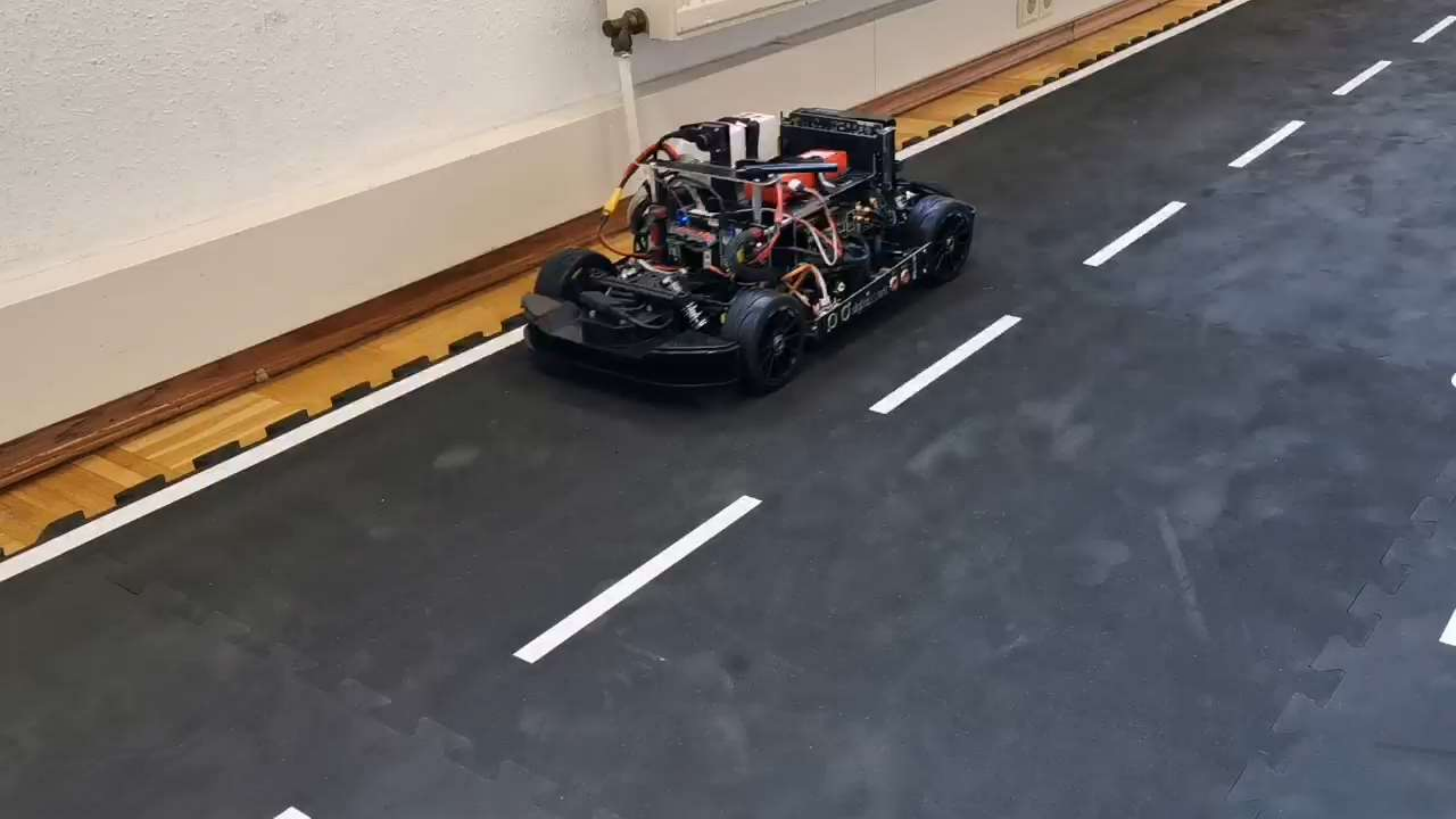
$$Comfort = 238\ °/s$$

Domain Adaptation

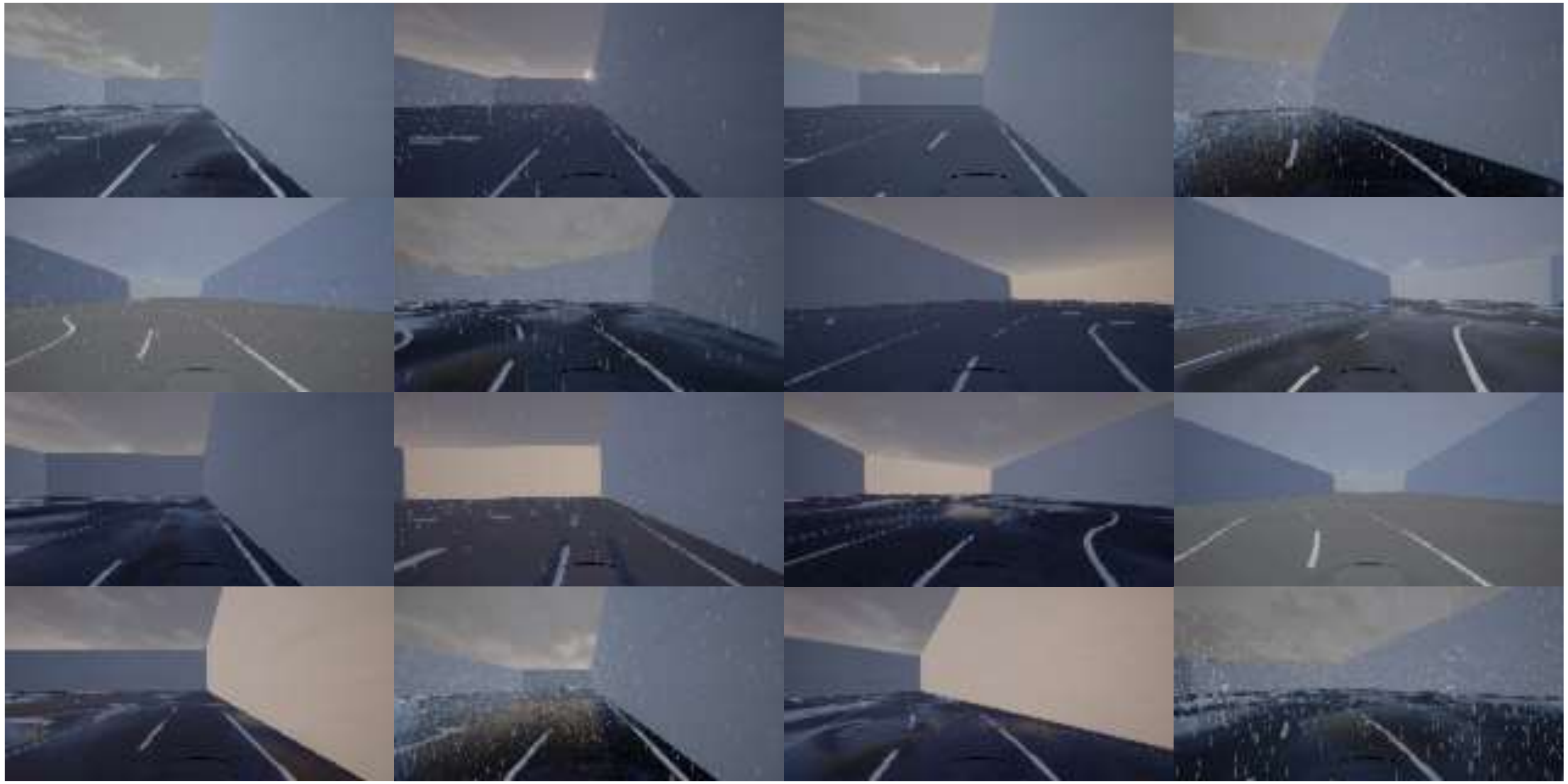


$$MDBF = "\infty"$$

$$Comfort = 29\ °/s$$



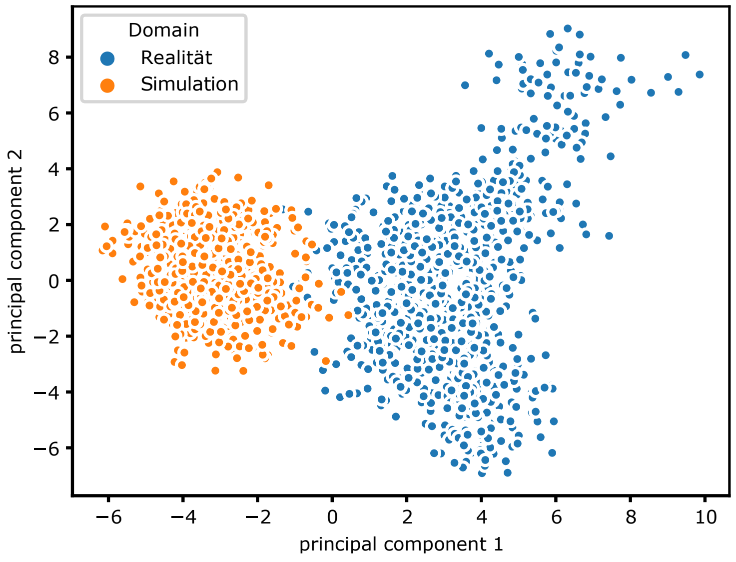
DOMAIN RANDOMIZATION (DR)



- Variation of weather and time of day
- 900 simulated images + 100 real images

DOMAIN RANDOMIZATION (DR)

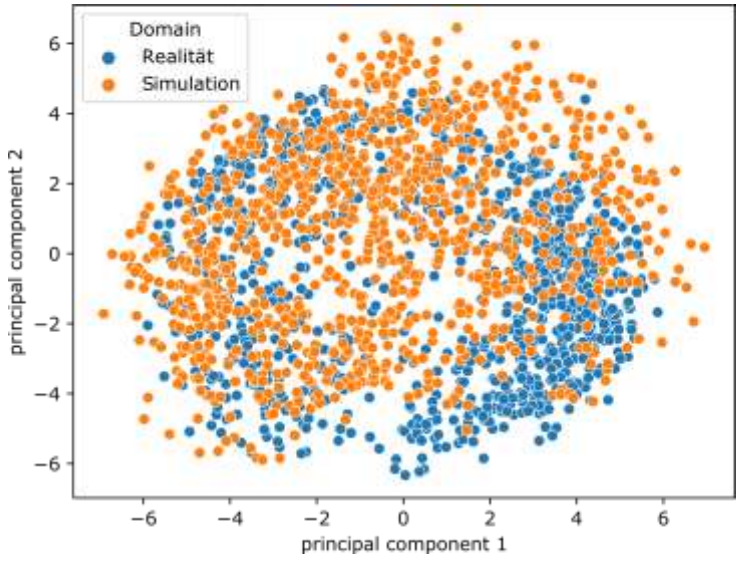
Baseline



$$MDBF = 4{,}07\ m$$

$$Comfort = 238\ °/s$$

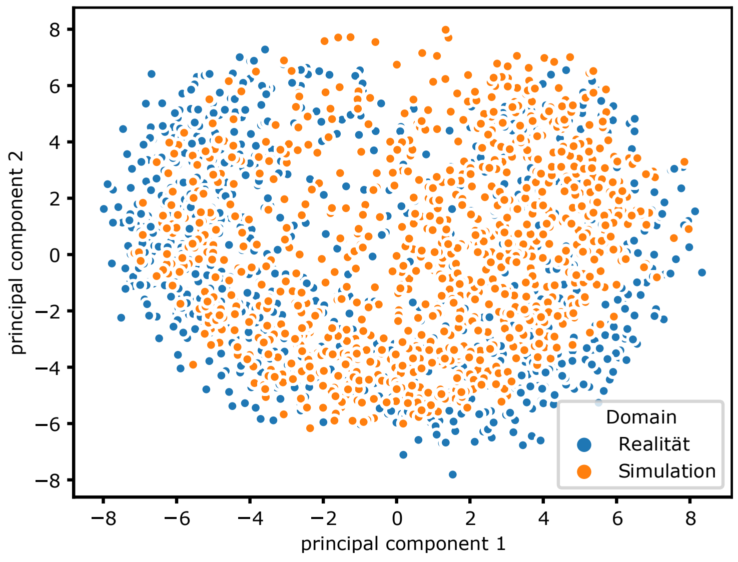
Domain Adaptation



$$MDBF = "\infty"$$

$$Comfort = 29\ °/s$$

Domain Randomization



$$MDBF = 134{,}31\ m$$

$$Comfort = 107{,}8\ °/s$$

EVALUATION

Evaluation over 20 laps (537.24 m)

DA

$MDBF = "\infty"$

DR

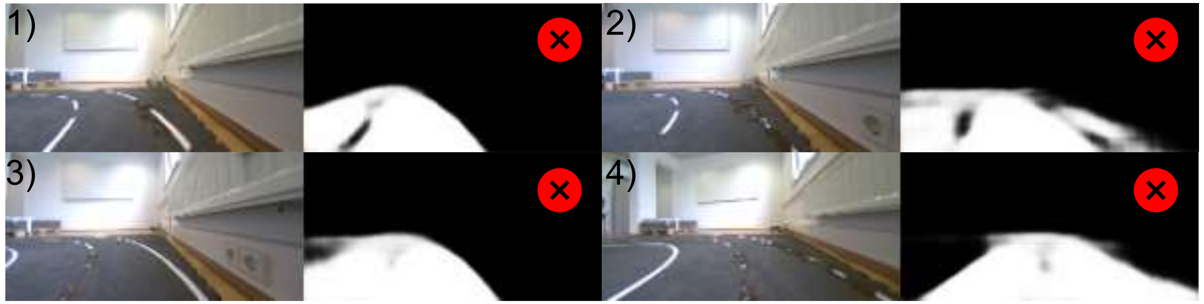
$MDBF = 268{,}62\ m$

Evaluation of difficult lighting conditions

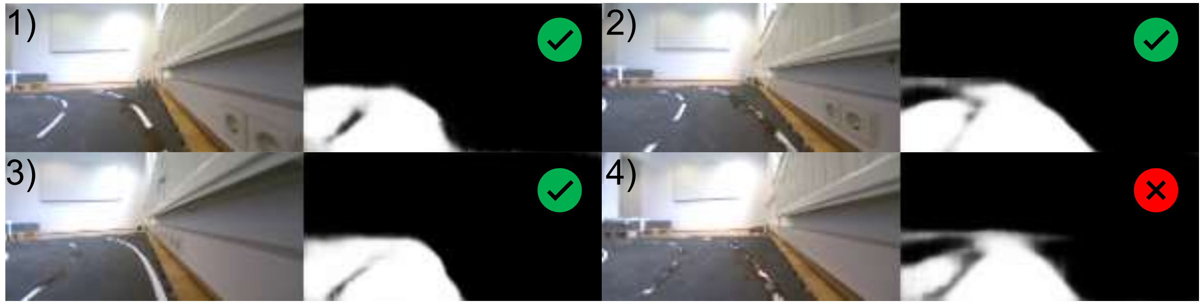
Lighting condition	MDBF [m]
Ideal conditions DA Ideal conditions DR	"∞" 134
Lights off, blinds open DA Lights off, blinds open DR	27 134
Lights on, blinds closed DA Lights on, blinds closed DR	27 67
Lights off, blinds closed DA Lights off, blinds closed DR	13 45

Evaluation of polluted roadway

DA



DR



RESULT

	DA	DR	DA + DR
> 20 laps without mistakes on the course	✓	✗	✓
> Calm, human-like driving behavior	✓	✗	✓
> As little labeled data as possible	✓	✓	✓
> Robust against lighting changes	✗	✓	✓

OUTLOOK

> Other simulation environment for domain randomization

> Record domain adaptation data under different conditions

> Evaluate more complex road and driving scenarios

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THANK YOU VERY MUCH!

Visit us on:
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