

# Highly-Modular and Immersive Human-in-the-Loop Driving Simulators Using the CARLA Simulation Environment



Photo: Gabriel Simmann

SIFAT

With funding from the:



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# Open and Modular Driving Simulators with CARLA



## Brief Biography of Patrick Rebling

### Education and Experience:

- Master's Degree in Automotive Systems Engineering from Karlsruhe University of Applied Sciences
- Software Development Engineer for Demonstrators for Automated Driving at ITK Engineering GmbH / Steinbeis
- Research Assistant at the Institute of Energy Efficient Mobility

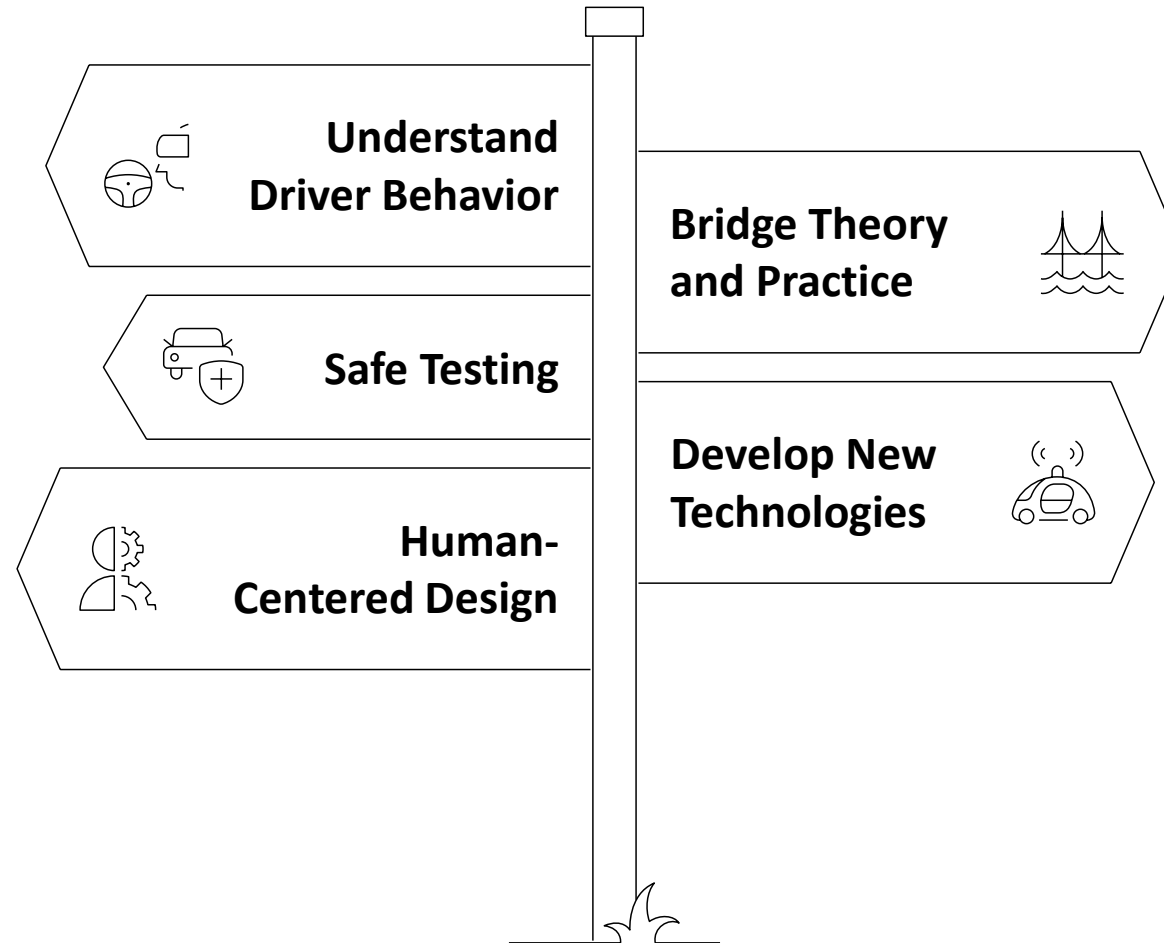
### Research Interests:

- Driving, bicycle, and pedestrian simulators for human-in-the-loop
- Modelling of human-like driving behavior
- Human-Machine-Interactions in mixed traffic scenarios



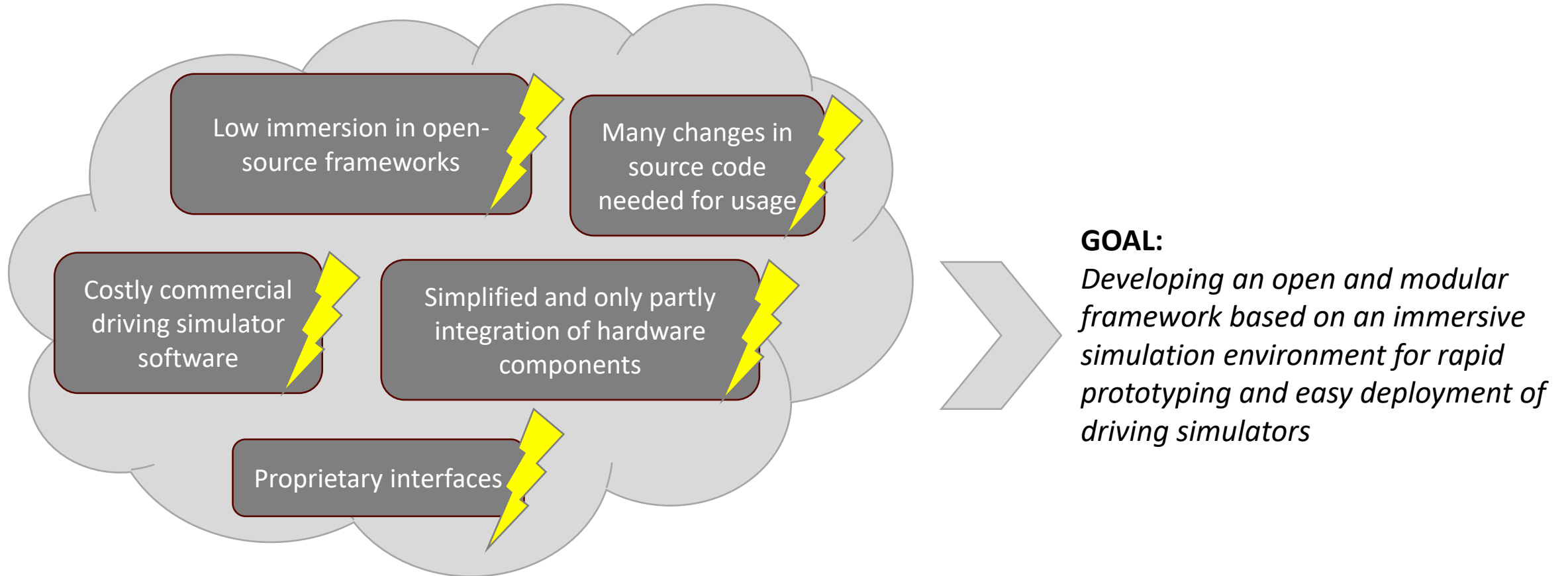
# Open and Modular Driving Simulators with CARLA

Why using human-in-the-loop driving simulators?



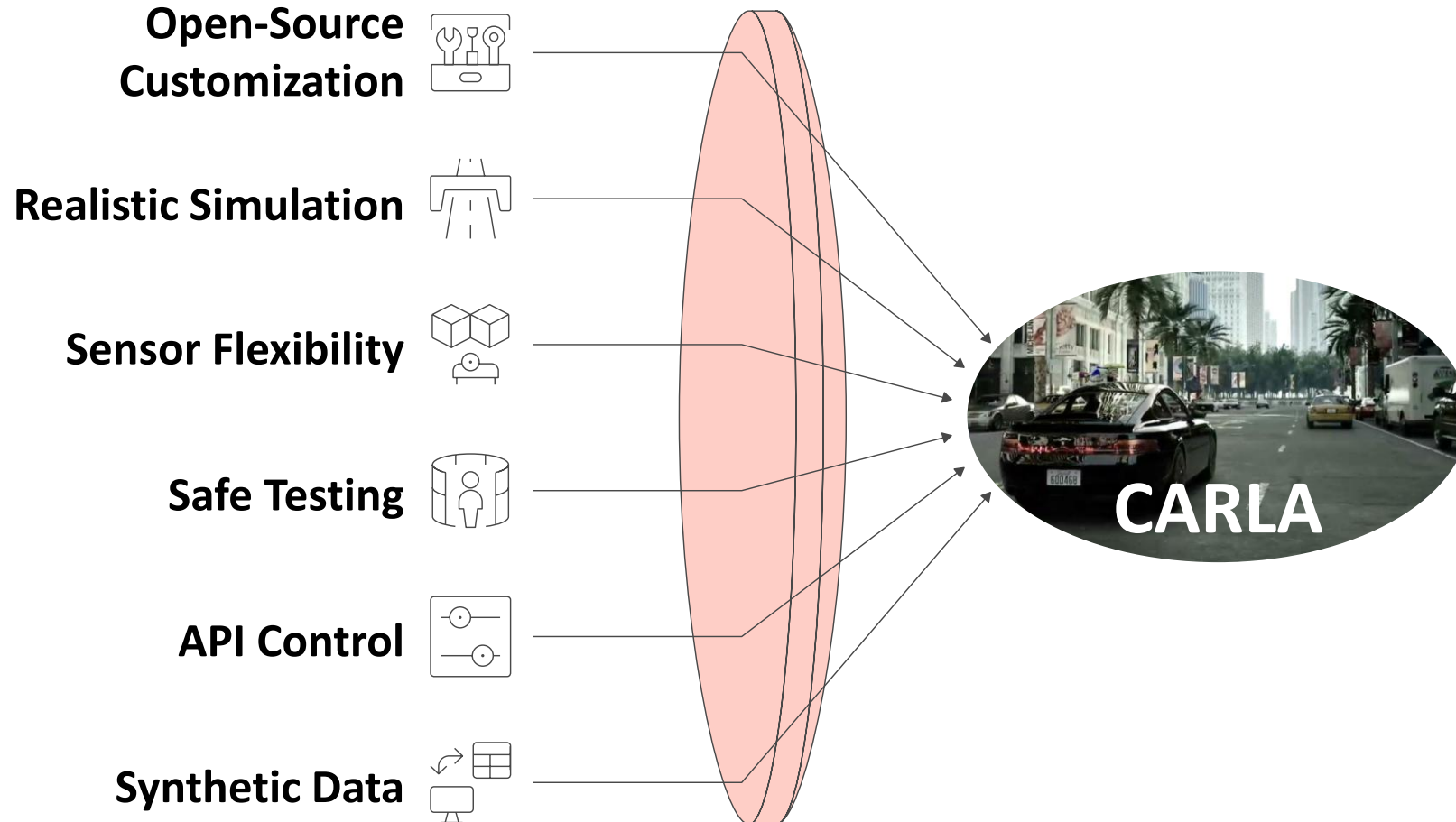
# Open and Modular Driving Simulators with CARLA

## Current Challenges and Our Goal



# Open and Modular Driving Simulators with CARLA

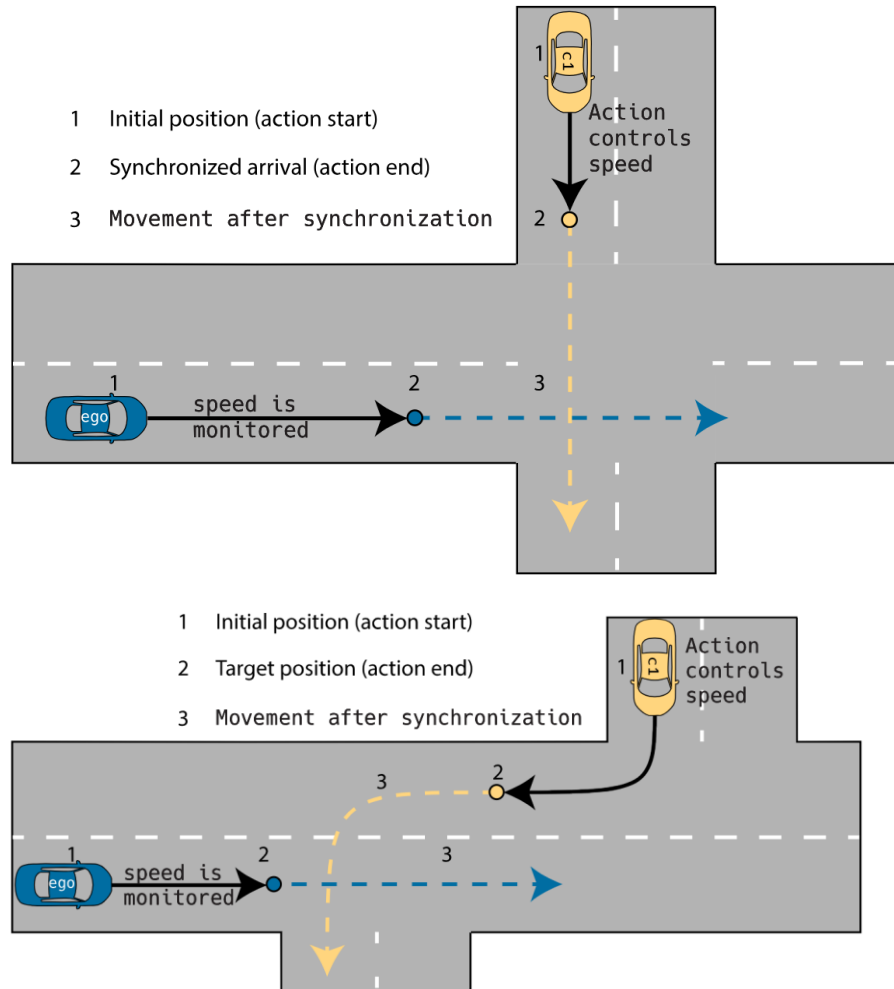
## Why CARLA?





# Open and Modular Driving Simulators with CARLA

## Scenario Generation and Execution in CARLA



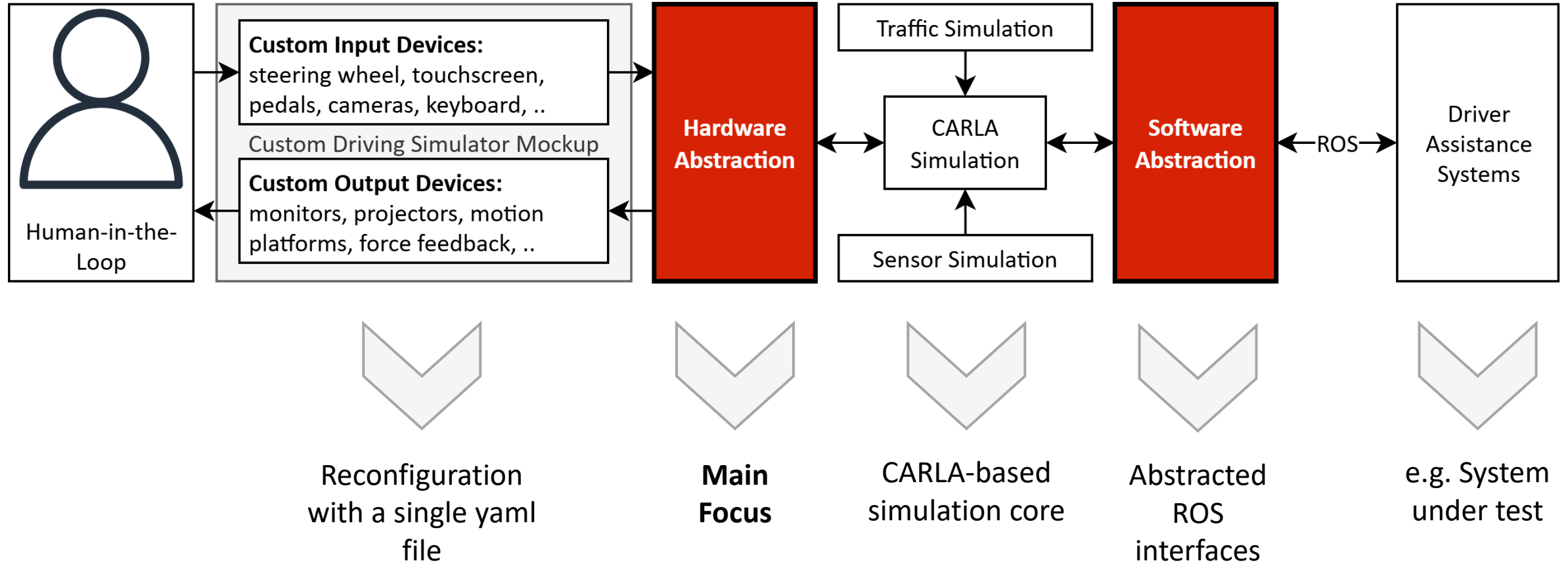
CARLA Scenario  
Runner /  
Leaderboard



Interactive simulator  
environment with  
deterministic traffic  
participant behavior

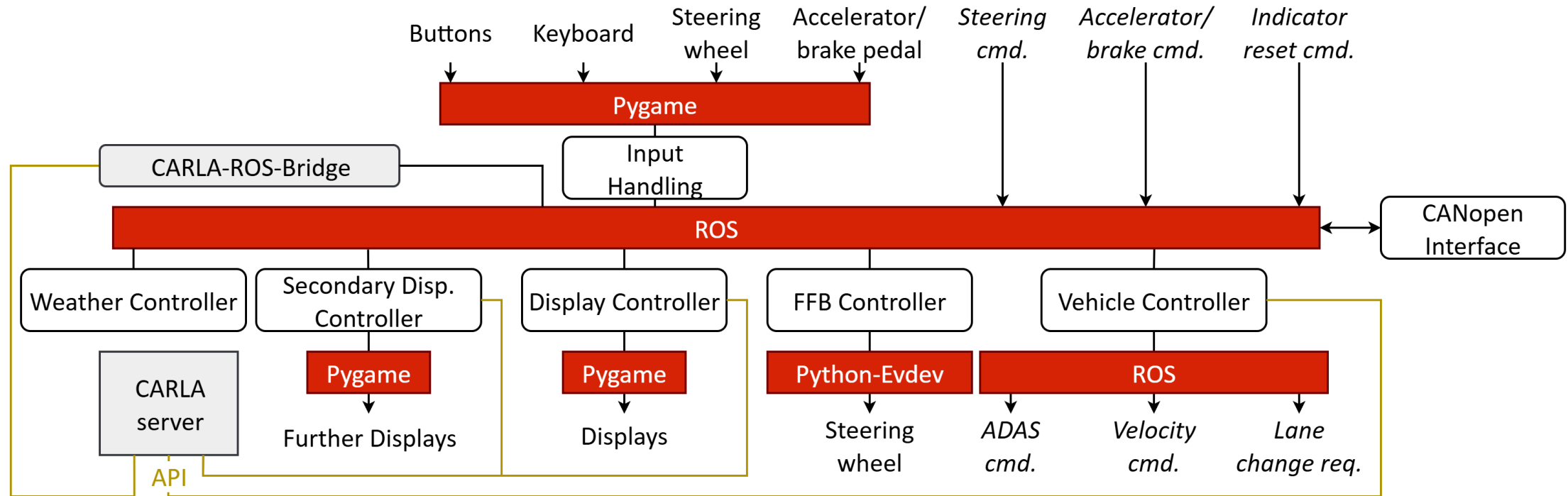
# Open and Modular Driving Simulators with CARLA

## Overview of Approach



# Open and Modular Driving Simulators with CARLA

## Approach in Detail

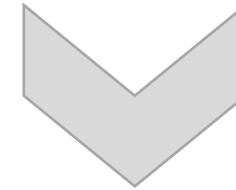
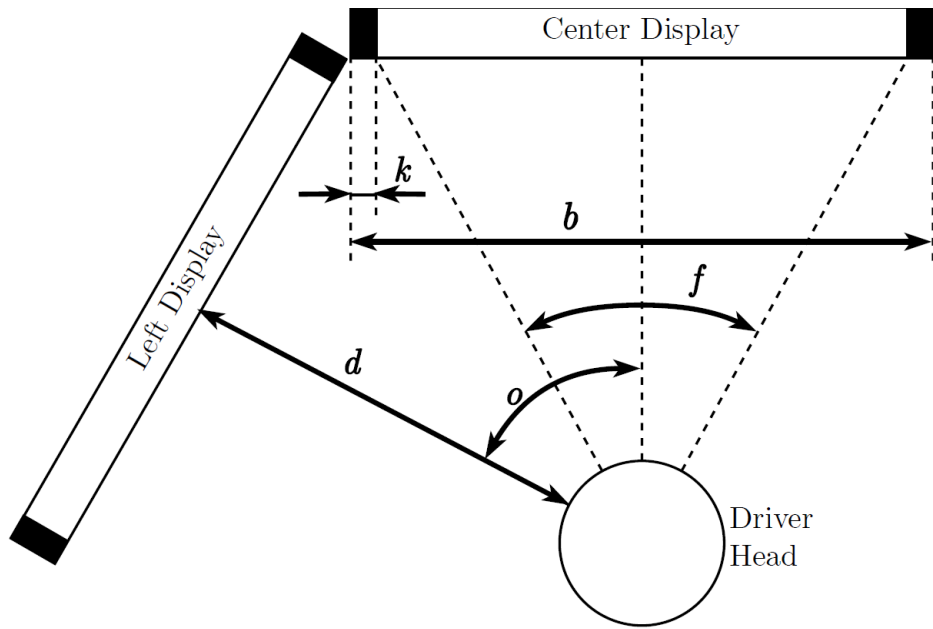


- Usage of ROS where data has to be logged
- Usage of API for performance relevant parts
- Display controller for mirrors and specific cameras
- State-Chart for vehicle light state
- Dynamic generated UI for dashboard and touchscreen interfaces
- CANopen interface for CAN communication (proprietary devices)



# Open and Modular Driving Simulators with CARLA

## Display Controller



- Determination of parameters of user setup
- Calculation of camera positions and rotations
- Resulting in seamless image on monitor setup
- Single monitor → single camera support

# Open and Modular Driving Simulators with CARLA

## Secondary Display Controller

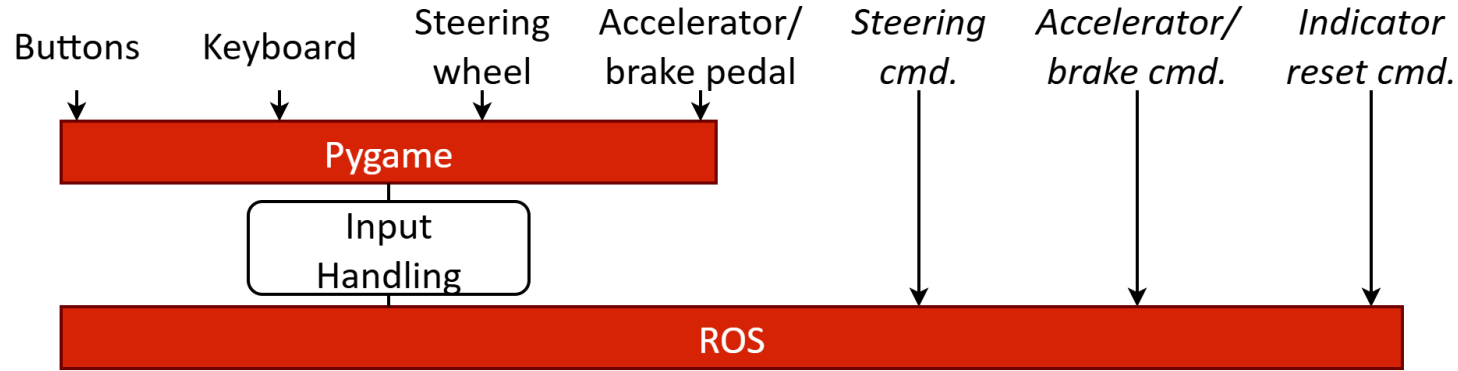


- Settings for rear mirrors
- Separated processes for multi-threading

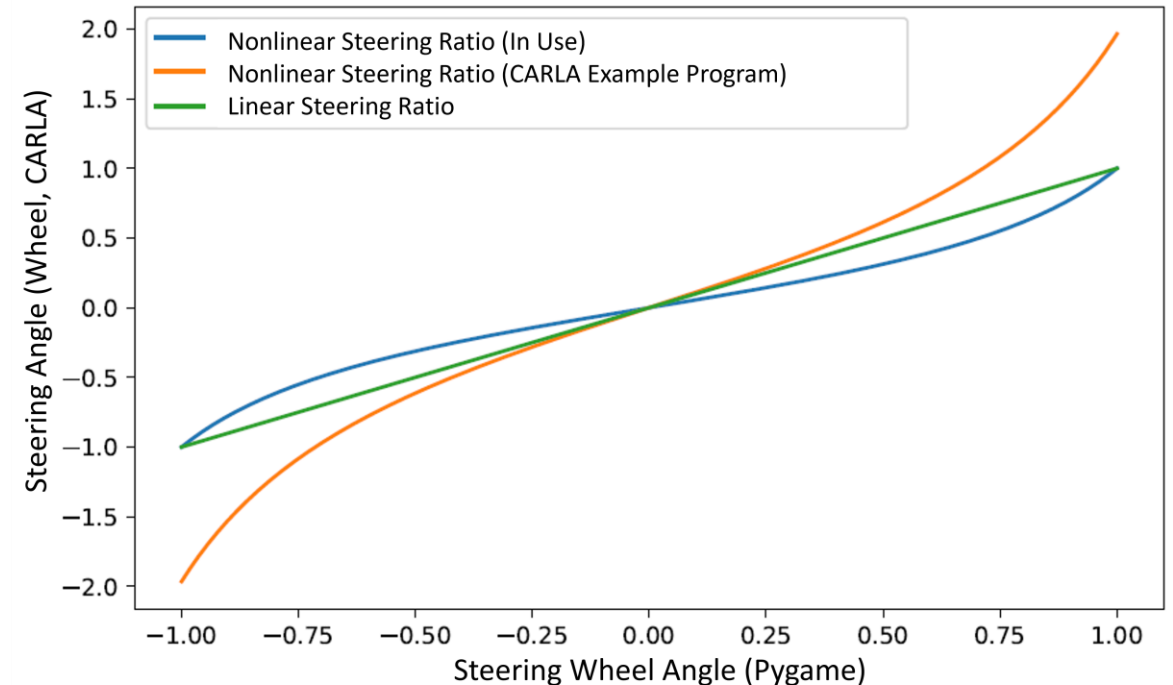
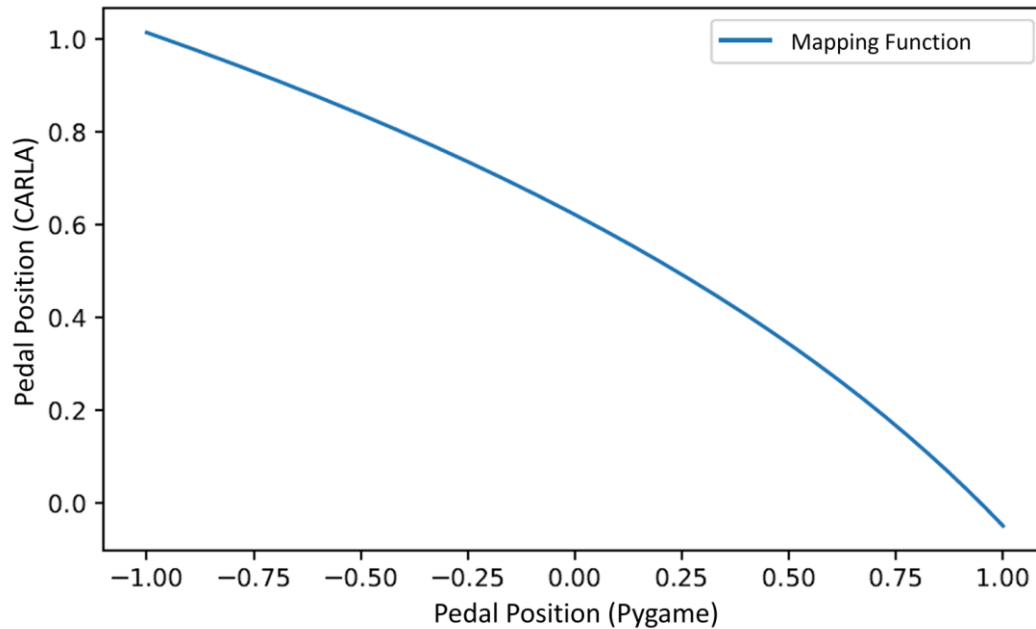


# Open and Modular Driving Simulators with CARLA

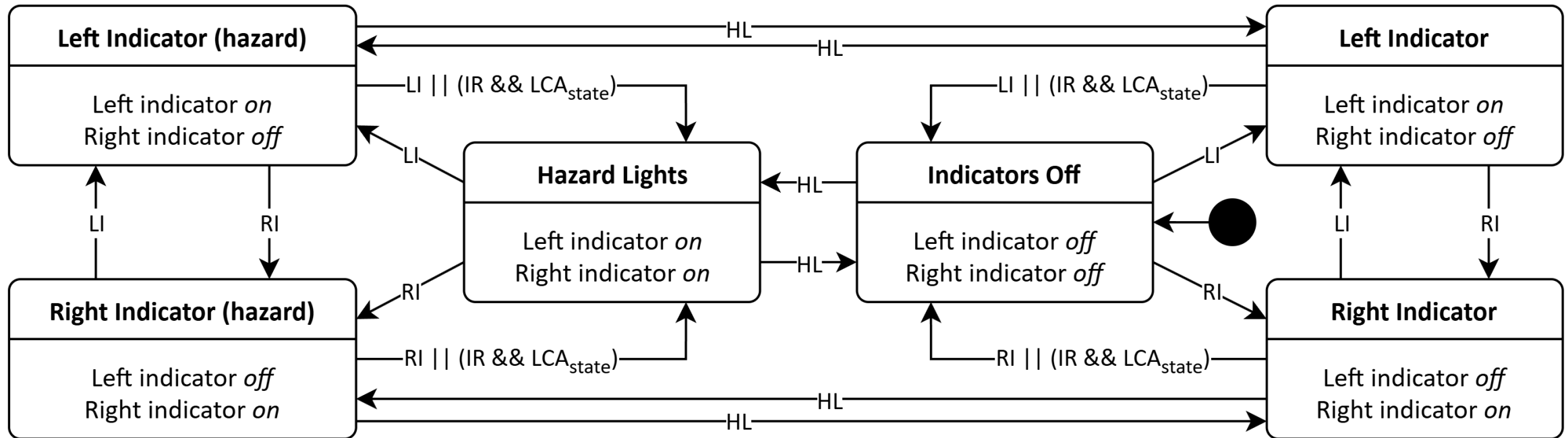
## Input Handling



➤ Mapping of raw inputs from joysticks into CARLA commands (as ROS topic)



## State Machine for Light Control



- State Machine for light control (especially indicator and hazard lights)
- State Machine is integrated into Lane Change Assists
- Position lights, low and high-beam are separated

# Open and Modular Driving Simulators with CARLA

## Force Feedback Control

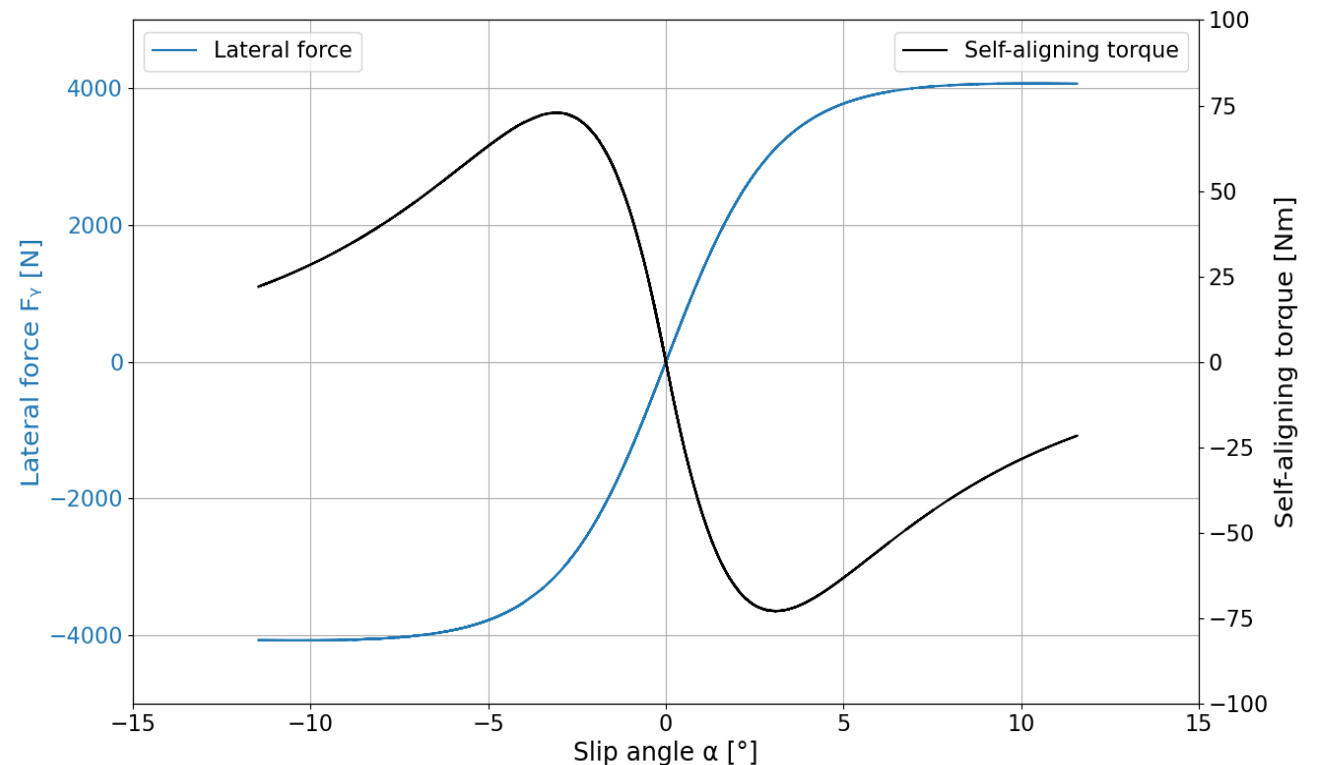
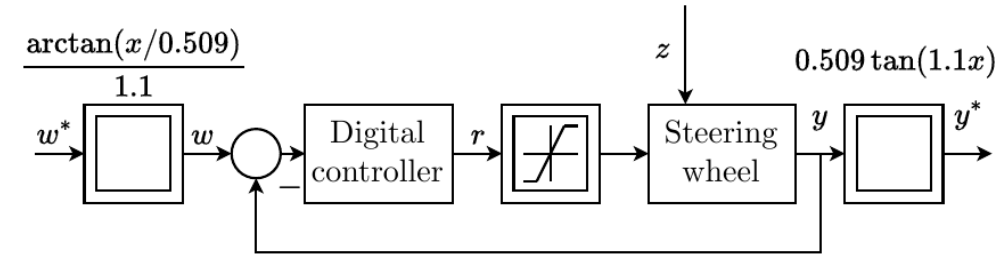
- Instead of vehicle wheel control, steering wheel control
- Active steering wheel while lane keeping
- Take over to driver by torque tracking:

$$T_{limit} \leq T_{current} \rightarrow \text{Disable LKAS}$$

- Realistic steering forces (e.g. Pacejka model)

### ➤ Support of

- Self-Aligning-Torque (Centering)
- Counter Torque
- Collision Impulses / Vibration
- Damping



# Open and Modular Driving Simulators with CARLA

## Reconfiguration for new Simulator Hardware

- Reconfiguration for new simulator hardware only needs adaptations to config file (best case)
- For proprietary hardware, abstracted interface classes are provided (e.g. for motion platforms)
- Configuration described in documentation for easy use



```
# control parameters #
control:
  ## joystick mapping ##
  joysticks:
    - index: 0
      axes:
        steer:
          axis: 0
          range: [-1, 1]
          dead_zone: 0.005
        brake:
          axis: 3
          range: [-1, 1]
          dead_zone: 0.005
        throttle:
          axis: 4
          range: [-1, 1]
          dead_zone: 0.005
    - index: 1
      handbrake_button: 1
      reverse_button: 0
      manual_gear_button: 2
      gear_up_button: 3
      gear_down_button: 4
```

### e.g. Control section

Joystick related information, steering and pedal axes defined here; ranges will be mapped to CARLA ranges

Further control buttons for CARLA on different joystick



# Open and Modular Driving Simulators with CARLA

## Reconfiguration for new Simulator Hardware



Simple driving simulator for development of the framework

Local Config File



Local Config File

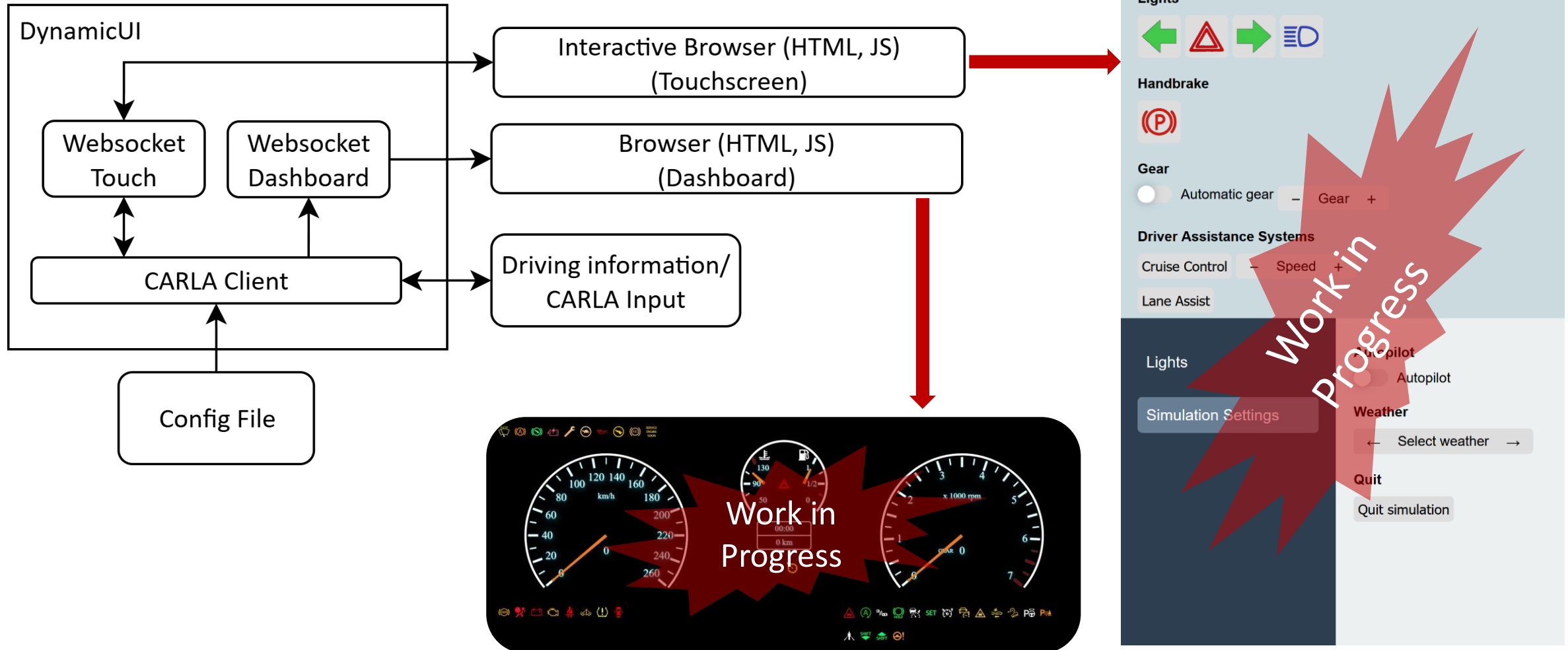


Local Config File

...

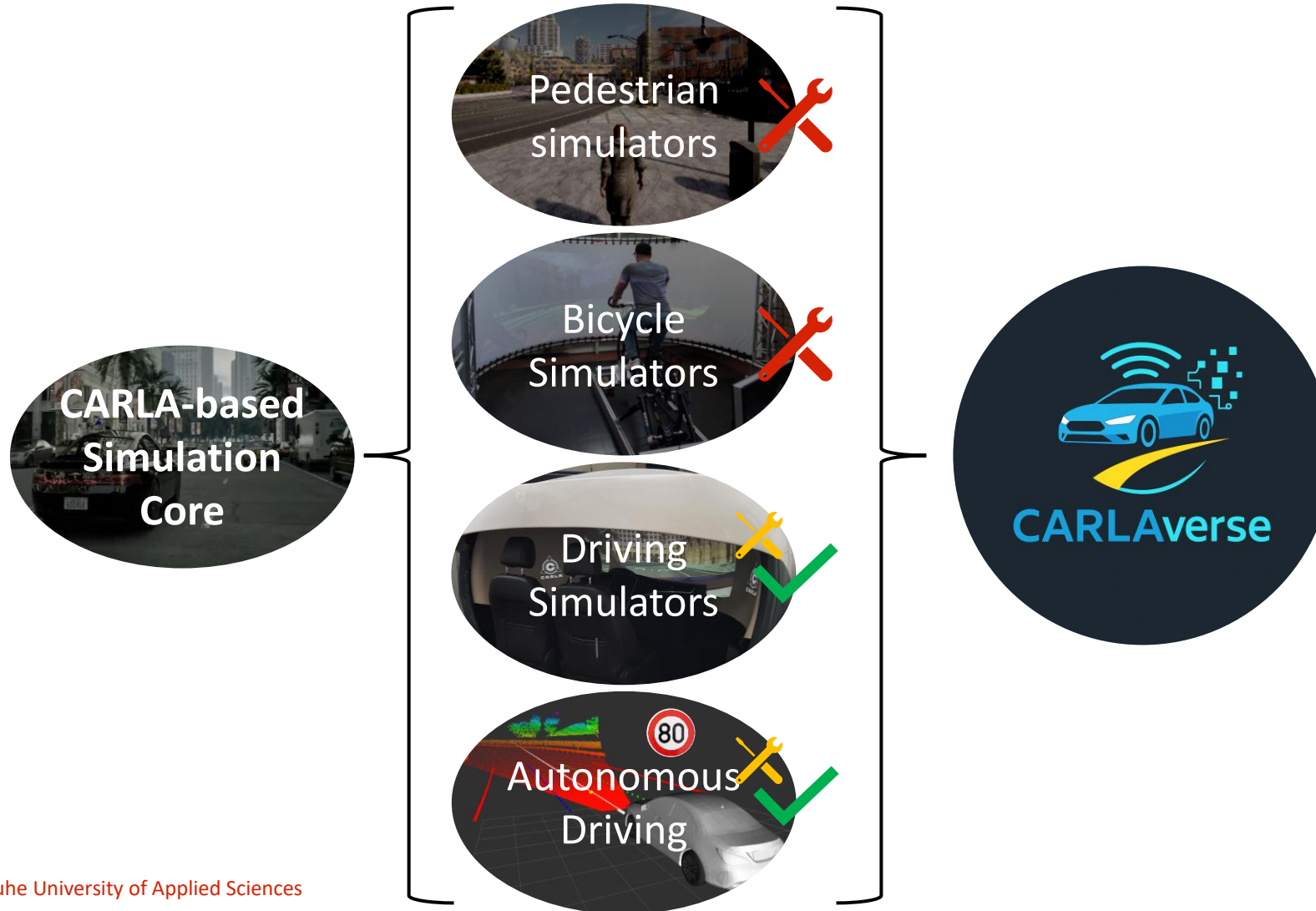
# Open and Modular Driving Simulators with CARLA

## Dashboard und User Interfaces



# Open and Modular Driving Simulators with CARLA

## Future Vision/Current Work: CARLAverson



- Base line for driving simulators and integration of autonomous driving functions is done
- Completely Open Source\*
- Multi-GPU, Multi-Server Support
- Connect different simulator types
- Connect multiple driving simulators
- Acoustics engine for CARLA
- Motion engine with motion cueing

# Open and Modular Driving Simulators with CARLA

## Summary

### Challenge:

- Existing simulators are either costly
- Proprietary or lack immersion
- Easy hardware integration

### Solution:

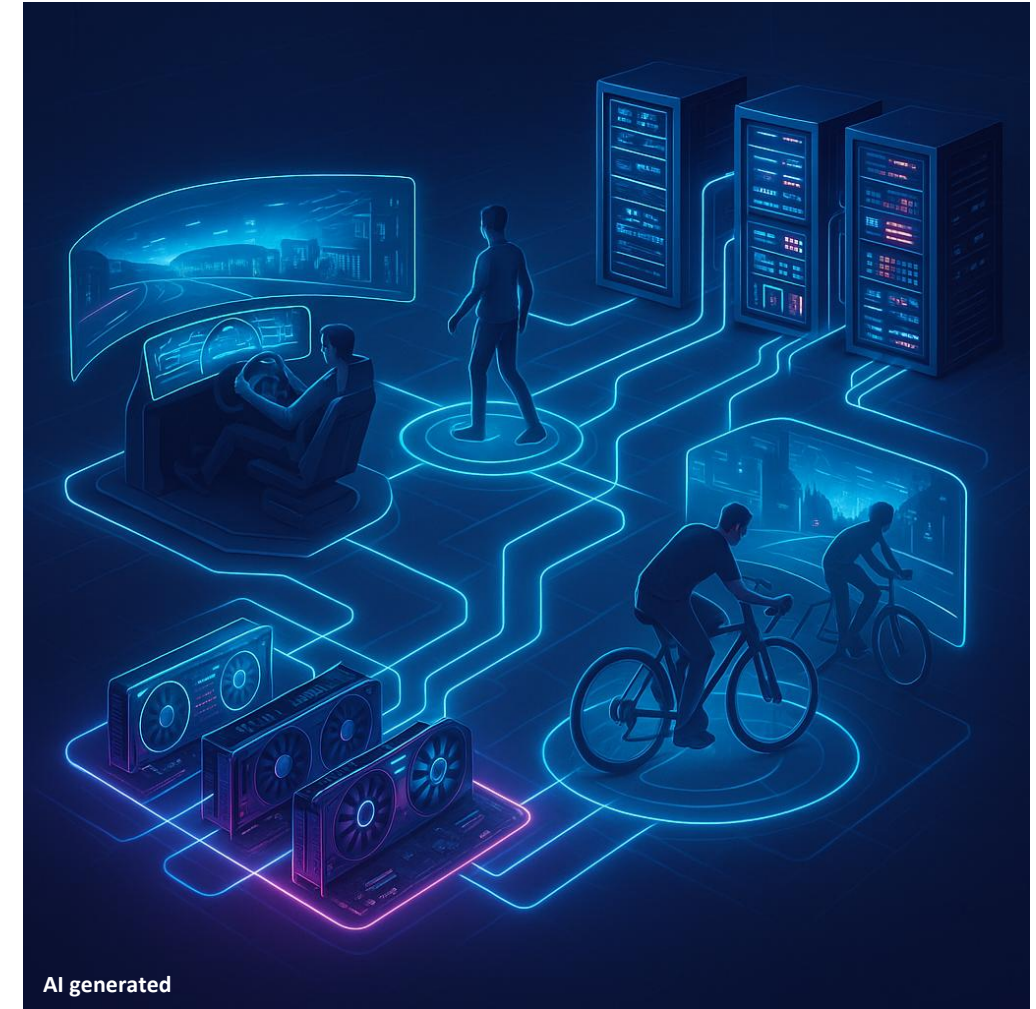
- An open, modular framework using CARLA for immersive and easily configurable driving simulators
- Baseline development completed

### Key Features:

- Abstracted interfaces and YAML configuration enable rapid hardware setup and easy reconfiguration

### Future Vision:

- CARLaverse – an ecosystem connecting multiple simulator types (driving, pedestrian, bicycle) with multi-GPU and multi-server support



# Thank you for your Attention

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With funding from the:



Supporters of the Driving Simulators:

