Using the Virtual Test Environment – System Integration and Flexible Scalability
Various application fields – diverse requirements

Simultaneous and sequential engineering

Different resources & platforms

PC  HIL SYSTEMS  TEST BEDS  HPC  CLOUD
Comprehensive model environment for virtual vehicle development

Open integration platform

Flexible & scalable

Designed for systems engineering & continuous integration
APPLICATION SPOTLIGHTS

ADAS & AD

POWER TRAIN

VEHICLE DYNAMICS

Steering system virtualization
Steering System Virtualization

- Perception & localization
- Data fusion & interpretation
- Trajectory planning
- Motion control
- Automated driving function

TEST SCENARIO

VEHICLE

Sensor models
Steering System Virtualization

- Perception & localization
- Data fusion & interpretation
- Trajectory planning
- Motion control
- Automated driving function

VEHICLE

Steering system as actuator
Steering Systems
Increasing interdependency with other vehicle systems

“Classical applications”

- EPS CALIBRATION
  Steering feel & vehicle DNA

- STEER-BY-WIRE
  Focus on control strategy

- REDUNDANT ARCHITECTURES
  Overtaking procedure & error handling

“Future trends”

- STEERING STRATEGY FOR AUTONOMOUS DRIVING
  Less steering feel with focus on overall comfort and vehicle dynamics

Complexity & test effort

Detailed steering model with realistic behavior necessary to develop highly interconnected systems
Steering System Virtualization
Methodology for detailed steering model
Steering System Virtualization
IPG Automotive is a solution provider

SIMULATION SOFTWARE
- Steering models with different levels of fidelity
- Flexible interfaces for steering ECU integration

TEST SYSTEM
STEERING-IN-THE-LOOP TEST BENCH
- Characteristic & performance tests
- Advanced steering system analysis (multiple ECUs, driver-in-the-loop,…)

IPG Automotive product portfolio

ENGINEERING SERVICES
- Model parameterization and validation
- Software and hardware integration
- Training and know-how transfer
IPG Automotive Steering-in-the-Loop Test Bench
Steering-in-the-Loop Test Bench – New Features

- Enhanced test bench flexibility
  - New Driver-in-the-loop extension
  - New Electrical height adjustment
- Increased test bench dynamics
  - New New sensor generation
  - New Test bench control with EtherCAT
IPG Automotive Engineering Services

Key services for steering system virtualization

- Reference measurements for steering model parameterization
- Steering model parameter identification
- Soft-ECU (EPS) integration
- Validation and parameter optimization
- Training and know-how transfer
IPG Automotive Engineering Services
Key services for steering system virtualization

- Reference measurements for steering model parameterization
- Steering model parameter identification
- Soft-ECU (EPS) integration
- Validation and parameter optimization
- Training and know-how transfer
Engineering Services
Reference measurements on Steering-in-the-Loop Test Bench

Characteristic tests
- Analysis of mechanical characteristics
- Static steering assist
- Steering stiffness, friction, damping,…

Performance tests
- Analysis of steering system performance
- With and without EPS operation
- Weave test, sine sweep, slalom,…

Operation without virtual vehicle

Operation with virtual vehicle
Engineering Services
Reference measurements on Steering-in-the-Loop Test Bench

Characteristic tests
- Analysis of mechanical characteristics
- Static steering assist
- Steering stiffness, friction, damping,...

Performance tests
- Analysis of steering system performance with and without EPS operation
- Weave test, sine sweep, slalom,…

Operation without virtual vehicle  Operation with virtual vehicle

NEW TEST CATALOG
LIVE DEMO
Steering system virtualization
APPLICATION SPOTLIGHTS

TestBed product line

Vehicle dynamics

Steering system virtualization

ADAS & AD

POWER TRAIN

VEHICLE DYNAMICS

Steering system virtualization
In 2020, emissions were 95 g/km, which decreased by 37.5% to 59 g/km by 2030.
2020 – 2030

CO$_2$

Emission Reduction

95 g/km - 37.5%

59 g/km

PENALTY

€95/(g*Vehicle)
2021++

Real-world CO₂ monitoring

- Mandatory onboard fuel consumption measurement devices for every car (4% precision)

- MARKET SURVEILLANCE:
  - Data of every car is collected
  - Gathered data is published and monitored
  - Real-world gap is made transparent for consumers

- Penalties for manufacturers that publish unrealistic data is intended
Powertrain megatrends

- ENERGY EFFICIENCY
- CO₂ ELECTRIFICATION
- ZERO IMPACT EMISSIONS
- RDX REAL-LIFE TESTING
The Nature of Innovation Is Changing
Shift from single to system-driven innovation

Component innovation
System innovation

POWERTRAIN INNOVATION BATTLE
CarMaker/TestBed – Launched!

A solution engineered around good ideas – Yours
CarMaker/TestBed – Launched!

Applications

- Virtual electrification
- Smart durability testing
- Attribute balancing
- Real-life range prediction
- Powertrain-to-X
- Driveability
- Powertrain calibration
- Real-life testing
- Virtual RDX
- Connected powertrain
- Enhanced flexibility

A solution engineered around good ideas – Yours
CarMaker/TestBed Setup at KIT (IFKM)

TEST CELL

Test bed control system

Closed loop
1-10kHz hard RT

Test bed

Dyno

ECU

Measured values (torque)

Set values (speed)

Test bed interface

CarMaker/TestBed

Real-time system

Road

Vehicle

Process integration tools

OPERATOR ROOM

Driver

Vehicle

Operator Room

TEST CELL
IPGDriver enhancements for test beds:
Pedal free play and shifting behavior

CarMaker open integration platform – Seamless usage of driver models
Stähle cycle driver model available
Service Contracts
Continuous solution support

Maximize availability and usability of your solution.
Avoid the high cost of operational downtime and inaccurate test results.
Everything will remain ... changed.

- Energy efficiency
- Safety
- Driveability / comfort
APPLICATION SPOTLIGHTS

AI training with synthetic data

TestBed product line

Steering system virtualization
Use of AI in Various Fields of Application
In the automotive industry

- Decision-making
- Image processing
- Trajectory planning
- Data analysis
What’s AI all about?
“Conventional” algorithms

**Function**

Output values = f(Input values)
What’s AI all about?
AI-based algorithms
Annotations – Bounding Boxes
Annotations – Semantic Segmentation
A simple math exercise...

**CHALLENGE:**

Produce 100,000 pixelwise semantically segmented images

- **3.5 minutes**
- **737.5 days**
LIVE DEMO

Semantic segmentation
VALUE
100% accuracy in annotation guaranteed

VELOCITY
Automatic generation

VARIETY
Free configuration of meta-information

VERACITY
Best results: data mix with real data

VOLUME
Nearly unlimited possibilities to produce data

POTENTIAL OF SYNTHETIC TRAINING DATA
CarMaker 8.0 Features at a Glance

- Annotation data (semantic segmentation) with freely definable object classes
- Depth map data in different configurations
- Color-rendering normals
- Material ID visualization
APPLICATION SPOTLIGHTS

- ADAS & AD
- POWER TRAIN
- VEHICLE DYNAMICS
- AI training with synthetic data
- Steering system virtualization
- TestBed product line
- Multiple GPU processing, HPC & cloud
Parallelization on CPU/GPU & in the Cloud
WHY IS PARALLELIZATION NECESSARY?

- Increasing complexity of systems and driving environment
- Increasing number of test cases
- Decreasing development cycles and testing time
Processing Resources Distribution with CarMaker

- Vehicle model
- Driver/Traffic model
- Environment model
- Ideal sensors

- Visualization
- Camera RSI
- Radar RSI
- Ultrasonic RSI
- Lidar RSI
Parallelization & Virtualization with CarMaker
Run several test runs at the same time with HPC

TEST RUN 1
TEST RUN 2
TEST RUN 3
TEST RUN 4

Vehicle
Road
Traffic
But Even Single Test Runs Can Be Demanding
Regarding the available computing power

Virtual prototypes consist of many different components/models

Scenarios with a lot of traffic/objects

Multi-sensor setups

Physical Sensor Models

Multi-domain
Parallelization in CarMaker
New Feature in CarMaker 8.0: Parallelization Also Within Test Runs

TEST RUN

CPU

GPU 1

GPU 2

GPU n

Distribution of demanding sensor setups on several GPUs
Example Sensor Setup

- 10 x Ultrasonic RSI
- 5 x Radar RSI
- 1 x Lidar RSI
- 1 x Camera
LIVE DEMO

Parallelizing a multi-sensor test run
LIVE DEMO

Parallelizing a series of tests in the cloud
Parallelization Within a Test Run and Over Several Test Runs

<table>
<thead>
<tr>
<th>Test Run 1</th>
<th>Test Run 2</th>
<th>Test Run 3</th>
<th>Test Run n</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPU 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPU 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Camera</td>
<td></td>
</tr>
<tr>
<td>GPU n</td>
<td>Camera</td>
<td>Camera</td>
<td>Camera</td>
</tr>
</tbody>
</table>

Test Run 1
- CPU
- GPU 1
- GPU 2
- Camera

Test Run 2
- CPU
- GPU 1
- GPU 2
- Camera

Test Run 3
- CPU
- GPU 1
- GPU 2
- Camera

Test Run n
- CPU
- GPU 1
- GPU 2
- Camera
Running CarMaker in the Cloud:
Example setup with 4 virtual machines
CarMaker

- is capable of running several test runs in parallel on multiple CPUs
- can parallelize demanding sensor setups on multiple GPUs
- and of course both at the same time
Demo at Booth: Video Interface Boxes

- **NVIDIA DRIVE PX2**
- **Video Interface Boxes**
  - 4 x GMSL
- **Host laptop / PC**
  - DVI
  - CarMaker
  - IPGMovie
- **HDMI**

**Connections:**
- 1 2 3
- 4 5 6 7
- 8 9 10 11
- 12
Simulation/Test Data Processing and Analysis

HPC and cloud computing leads to big data results

- Classical post-processing tools
  - Relational and data bases
    - Structured data
    - Vertical scaling

- Big Data Analytics
  - Unstructured data
  - Horizontal scaling

Conventional simulation data volume

Big simulation data volume
Big Data Analysis
Data remains in place and can be accessed right away

- **FAST** Big data analysis in very short time (distribution on multiple CPU/GPUs)
- **FLEXIBLE** Online analysis as well as post-processing
- **EXTENSIVE** Suitable for non-structured data (e.g. pictures, videos, etc.), advanced analytics (e.g. AI algorithms, easy mapping with external data)
Big Data Analysis with DaSense by NorCom
Advanced analytics and AI on worldwide distributed data

Open architecture for scalable processing
- Interactive, batch/post-processing, online
- On-premise and cloud

Made for the enterprise
- Secure integration of data and infrastructure
- Intelligent data management and team collaboration

Advanced analytics incl. AI for automotive
- Managed integration of the latest AI methods
- Powerful automotive modules already included
SIMULATION WORKFLOW

DATA SOURCES

SCENARIO

VIRTUAL PROTOTYPES

SIMULATION & TEST EXECUTION

RESULTS

VARIATION & EVALUATION CRITERIA

SIMULATION DATA MANAGEMENT