Virtual driving tests for efficient function development & testing

Vector India Conference - Pune
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Cornelius Chucholowski developed real-time capable vehicle models at BMW as a freelancer from 1985.

He founded TESIS in 1992.

Main products veDYNA and enDYNA with models for vehicle dynamics and engine dynamics.

Additional engineering services.

DYNA4 succeeds veDYNA and enDYNA with higher modularity and stronger simulation process support.

Ongoing model extensions and improvements.

Vector acquires TESIS in 2019.
Brief History of DYNA4

DYNA4 Model Packages today

- **Vehicle dynamics** for passenger cars, commercial vehicles, trucks and trailers
- Conventional, hybrid or electric drivetrain configurations
- **Traffic** environment and sensor models
- Thermodynamic engine models
- All models run in real-time or much faster

Effect of tire inflation modelled with TMeasy tire model and multi-body chassis

Hybrid control strategy optimization with powertrain models on virtual dynamometer

Virtual Lidar sensor with point cloud output in urban scenario with multiple road users
Brief History of DYNA4

Use-case dependent choice of fidelity and integration of custom models
Traditional and still valid reasons for virtual test driving:

- reduction of cost for prototypes
- increased front-loading to avoid costly changes in late development phases and
- increased efficiency through test automation.

Higher automation and more complex software require even deeper usage of simulation:

- software development processes (agile development, continuous integration ...) not compatible with limited capacity of real prototypes
- non-deterministic behavior of artificial intelligence increases scenario and mileage quantity and
- interdependencies between different functions require early integration of functions before a real prototype is available.

Why do we need virtual test driving?
Key Components for Virtual Testing of ADAS and Automated Driving

**Traffic**
- vehicles, bicycles, pedestrians, animals
- deterministic tasks or stochastic traffic
- interaction with other road users and reaction on events

**Your ADAS/AD functions under test**
- MiL/SiL test and development with control algorithms
- HiL testing with hardware ECUs

**Environment Sensors**
- object lists, target lists or physics-based sensor data
- camera, radar, lidar, ultrasonic
- vehicle dynamics for realistic sensor movements

**Vehicle under Test (VuT)**
- realistic vehicle dynamics
- actuation of engine torque, brakes, steering, etc.
- vehicle states sensors
- driving tasks for driver

**Road & Environment**
- road with lane markings
- traffic signs and signals
- terrain, buildings, vegetation
- lighting, fog, precipitation
Key Facts Vehicle Dynamics in DYNA4

- **Chassis**
  - Multi-body-system vehicle dynamics model approach with up to 30 DoF for each axle
  - Alternatively tabled axle kinematics from K&C measurements
  - Consideration of external influences (e.g. wind impact)

- **Tires**
  - TMeasy 5 tire model with precise contact forces even for standstill
  - Easy parametrization with physical values
  - Simulation of inflation pressure

- **Steering**
  - Universal joints
  - Different EPS configurations
  - Integration of 3rd party steering models (e.g. Bosch Automotive Steering)
OpenDRIVE road format

- ASAM standard for parametrical road model and static environment
  - Complex road networks with junctions, crossfall, superelevation etc.
  - Road marks and barriers, traffic signs and traffic lights, gantries, etc.
  - Integration of high resolution road surface profiles in OpenCRG format

- Direct support without conversion in DYNA4
  - Online generation of road and terrain for simulation and 3D visualization
  - Simulink block for online access to ground-truth road data

German highway A9 measured and exported to OpenDRIVE by 3DMapping
Chances and Challenges of Virtual Test Driving

Unity-based visualization for detailed environment modelling
Assign paths or routes to road users (vehicles, cyclists, motorbikes, pedestrians, animals)

Trigger longitudinal or lateral driving tasks such as lane changes for deterministic behavior

Enhance deterministic traffic with stochastic road users

Complex traffic signal control for urban scenarios

Control lighting and weather of the scene in simulation scenarios

Outlook: Active contribution to OpenSCENARIO standardization
More than Traffic: Multiple Vehicles under Test (Multi-Ego)

- All ego vehicles with precise vehicle dynamics, even truck-trailer combinations
- Integrate different control strategies for each of the active ego vehicles
- Development of connected vehicle functions, e.g. platooning
- Surrounding traffic with deterministic or stochastic behavior
Chances and Challenges of Virtual Test Driving

DYNA4 Sensor Model Approaches

- Sensors are crucial for environment perception of ADAS/AD algorithms

- DYNA4 offers **sensor models with different levels of detail** depending on the use-case

1. **Simulink-based:**
   - fast and idealized sensor models
   - calculated with CPU only
   - fully integrated in Simulink

2. **GPU-based:**
   - physics-based advanced sensor models
   - calculated with GPU-technology
   - object list, camera, ultrasonic, lidar and radar
Chances and Challenges of Virtual Test Driving

Customer Example with Camera Sensor Sensors in Valet Parking Scenarios

- **Camera Sensor**
  - Adjustable distortion (OpenCV or Scaramuzza) and color filters
  - Output: RGB image stream
  - Synthetic parking garage included in object catalog
  - Integration of real-world garage objects possible, e.g. measured by Promotives
  - TMeasy tire model advantageous in low speed maneuvers

Virtual camera: feature detection for visual inertial odometry
DYNA4 Interfaces to other Tools and Models

- DYNA4 can be **Master or Slave**
- Customer examples of **other components in DYNA4**:
  - Vehicle Dynamics: VI-grade, CarMaker
  - Visualization/sensors: rFpro, VTD, PreScan, (OTSL), (Optis)
  - Powertrain: Amesim
  - Traffic Simulation: SUMO
  - Tires: MFTyre, FTire
- **Integration into other tools** through:
  - Model export as FMU
  - External control of DYNA4 through API: e.g. Exam and other automation tools
  - Flexible interfaces: ROS, ...
  - Export of stand-alone runtime applications: CANoe, ADTF, ...
DYNA4 Interfacing to ROS2

Vehicle & Traffic Simulation

3D Visualization incl. virtual sensors, point cloud, camera images, etc.

ROS2 Library

DDS

Vehicle states

Control signals

Motion data

Sensor output

Driving control

Trajectory planning

Environment detection

ROS
DYNA4 Interfacing to ROS2
DYNA4 Export for CANoe as Headless Runtime Model

**Tool Interaction**

**DYNA4**
- Model & Scenario Export

**vTESTStudio**
- Test Design

**CANoe**
- Test Execution
  - Node-layer DLL & Datasets

**vVirtualTarget**
- virtual ECU

**VTSystem / VNx**
- or
- hardware ECU
Distributed Systems

- Development and test of distributed systems with interconnected participants:
- System environment needed as well as the “real world” to keep a subsystem “alive”
- Use models as appropriate, problem-oriented description of a real system
- Models for the environment to be able to execute tests in virtual test environments
- Models for subsystems for the following phases:
  - Phase 1:
    System design based on models only
  - Phase 2:
    Development and test of subsystems in early stages, independent of availability of other subsystems
  - Phase 3:
    Integrate the entire system step-by-step
System Simulation and Test with Vector Tools

Test Management
- Requirements
- Test Cases
- Test Planning
- Test Result Analysis

Vector Tools
- Test Design
  - vTESTstudio
- Simulation Model / Test Execution
  - CANoe

Additional Models
- Matlab
- DYNA4

SUT: real or virtual for SIL, MIL and HIL

Vector Network Interfaces
- Direct Integration
- Shared Network Variables
- ASAM XIL API
- FDX

Other 3rd party tools
- .NET DLL
- FDX
- ...ROS

Customer Models
- FMI

Requirements
- ReqIF Exp.
- Trace Items
- Traceability Matrix
- Report

Test Cases
- Test Planning
- Test Result Analysis

Test Management

Test Cases
- Test Planning
- Test Result Analysis

SUT: real or virtual for SIL, MIL and HIL
For more information about Vector and our products please visit

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