Virtual Homologation of Software-Intensive Safety Systems: From ESC to Automated Driving

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Homologation and Type Approval

**Definition**
Homologation refers to the certification process of a product (vehicle) granting that it complies with all local standards and legal regulations such as safety and environmental regulation.

No homologation → No CoC → No sales

**Self certification vs. type approval 3rd party principle**

**Type Approval in vehicle development**
- Last step of development
- Accomplishment of the v-cycle
- Legal and technical approval of the concept

- European Union: Directive 2007/46/EC Type approval, tests are based on United Nations Economic Commission for Europe (UN/ECE) procedures;
- North America: Federal Motor Vehicle Safety Standards (FMVSS) regulations released by the NHTSA;
- Australian Design Rules (ADR) regulations;
- Japan follows UN/ECE regulations and their own Test Requirements and Instructions for Automobile Standards (TRIAS) regulations;
- Other countries that accept or base their own regulation on those mentioned above, following the latest release or previous versions of the regulations.
Using Simulation in Homologation

**Using simulation in vehicle development and testing**

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Simulation is used at different testing levels through the development cycle
- Software in the loop
- Model in the loop
- Hardware in the loop
- Vehicle in the loop
- Driving simulators

Can Simulation be used in the homologation process?

Motivation for simulation (virtual methods) in homologation

- Vehicle variant complexity
- Increasing active systems
- System complexity
- Huge testing parameter space
- not reasonably coverable by physical testing
- Limitation of physical testing

Highly relevant for ADAS and for automated driving
Assessment of ADAS/AD Systems

Assessment Results

Virtual Assessment

- SW in the Loop
- HW in the Loop
- Driving Simulator

Vehicle Testing (NDS, fleet, proving ground, …)

Model Database

- Scenarios (exposition, environment, …)
- Road Users (driver, pedestrian, …)
- Vehicle (driving dynamics, …)
- Sensors (radar, lidar, camera, …)

Legend:

- 10⁰ scenarios
- 10¹ scenarios
- 10² scenarios

Situation space mainly covered by virtual assessment

Models: 
- Relevant situations for further investigation
- Validation, verification

Source: Requirements on tools for assessment and validation of assisted and automated driving systems, Udo Steininger, TÜV SÜD Auto Service, Dr. Hans-Peter Schöner, Daimler, Dr. Mark Schliempf, BMW
Homologation of ADAS & Active Safety Systems: Current Situation

Periodic Table of Automobile Safety Features

- **UN-ECE R13/H**: Braking heavy vehicles, Braking passenger cars
- **UN-ECE R79**: Steering Equipment
- **UN-ECE R123**: AFS Lamps
- **UN-ECE R130**: Lane Departure Warning Systems
- **UN-ECE R131**: Advanced Emergency Braking Systems
- **UN-ECE R139**: Braking Assist Systems
- **UN-ECE R140**: Electronic Stability Control (ESC) Systems
- **UN-ECE R141**: Tyre Pressure Monitoring System
Homologation of ESC (Electronic Stability Control)

ECE-R 140 allows for simulation methods to support the homologation of electronic stability control systems (ESC)

01 Define the vehicle representative of the type to be homologated, and test it under the dynamic maneuvers.

02 Generate the vehicle simulation and correlate the obtained data

03 Simulate critical variants

Sine with Dwell (SwD) maneuver

Approval testing & collecting data

Model validation

Approval & assessment of variants by using validated simulation model
Core Elements of the Simulation Aided ESC Homologation Process

- **test input**
  - vehicle type definition
  - vehicle preconditioning

- **real vehicle**

- **vehicle model**
  - (ESC) function model

- **simulation**
  - simulation tool(s)
  - vehicle models with parameters
  - function models with parameters
  - validated models

- **(real) test results**
  - output definition
  - measurement channels
  - relevant data
  - post processing

- **(simulation) test results**

- **results**

- **evaluation**
  - evaluation procedures
  - key performance indexes (KPI)

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**How portable is the approach to highly automated driving?**
Vehicle parameter variation is sufficient

- principle of homologation remains the same
- new parameter dimensions
- Exploding number of testing parameters and parameter combinations
- Uncertainties increase
- Consequences are more severe

→ Scalable and flexible homologation
→ Simulation aided/supported homologation for HAD functions

Vehicle parameter & situation variation are necessary
Adopting the Approach of ECE-R140 for Automated Driving

Maneuver / scenario data base
- description
- parameters
- fail/pass criteria (KPI)

- subset for homologation
- subset for physical testing
- subset for simulation testing

- test track
- real vehicle
- virtual vehicle

results: \(m\) vehicle variants \(\times\) \(n\) scenario variants \(\times\) …

How to bring the virtual vehicle in the virtual test track (simulation)?
Possible Architecture for Virtual Test/Homologation Cell

- **test management**
- **scenario data Base**
  - test case generation
  - test automation
  - observation measurement KPI’s evaluation
  - behavior models of KPIs for characterization

- **ENV SENSORS**
  - Ultra sonic
  - RADAR
  - Camera

- **DRIVER**

- **virtual test cell**
  - (manufacturer) vehicle model
  - HAD functions

- **test platform architecture**

- **environment simulation road / traffic / ambient**
  - ground truth object lists
  - ground truth video stream

- **ground truth video stream**
Hear Nothing, See Nothing, Say Nothing: How to Deal With the Sensors?

Homologation is about (concept/functionality/principle) verification, but which kind?

- **perception**: It perceives the right things
- **interpretation**: It figures out the correct situation
- **reasoning**: It takes the right decisions
- **acting**: It acts the right way
- **executing**: It executes what is supposed to do

1. Starting from UNECE R140
2. Update UNECE R79 + new Regulation (longitudinal and lateral control)
3. Integrate function models into homologation process
4. Virtual homologation

**S**: Consider new single regulations for single sensor homologation

Physical (real) tests → Effort → Coverage/scalability

Virtual (simulation) tests

Validated sensor models → Effort

Validated function models

Validated interpretation models

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Model Validation: A Mandatory Step towards Virtual Homologation

Model states (e.g. steering, yaw angles) shall meet reality within a defined accuracy

Simulation shall take the right decisions with respect to reality/specification

Simulation should recognize the same situation as predefined

Simulation shall sense the environment exactly

Just drive safely without accidents at any traffic situation

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**Domains**: road dynamics, vehicle dynamics, E/E functions, sensors, static surrounding, dynamic surrounding, traffic, weather

**Validation criteria**: UN-ECE R140 (R13/R79)

**Category**: executing, acting, reasoning, interpretation, perception
Thanks for your attention!

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