Level 2+ Advanced Driver Assist Algorithm Prototyping via Model Based Design
Yue Sun Et al.
AVL Company Overview – One Global Partner

**RESEARCH**
10% of turnover in-house R&D

**INNOVATION**
1,500 granted patents

**STAFF**
10,300 employees
65% engineers & scientists
300 engineers in NA

**GLOBAL FOOTPRINT**
30 engineering locations
- >220 testbeds
- Global customer support network

**GROWTH**

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales (billion €)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>0.15</td>
</tr>
<tr>
<td>2017</td>
<td>1.55</td>
</tr>
<tr>
<td>2018</td>
<td>1.81</td>
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**SERVICES**
powertrain to vehicle integration

70 years of experience

**SALES**

- Austria
- France
- Germany
- Great Britain
- Italy
- Hungary
- Sweden
- Turkey
- South America
- North America
- USA
- Asia
- China
- India
- Japan
- Korea
- Europe
- Brazil
AVL’s Lv2+ ADAS/AD Function Offerings Via MathWorks Toolchain (MBD)

**Rapid development & white-box libraries**
- Localization
- Motion Planning & Control
- Sensor Fusion

**Platform agnostic & open partnership functions**
- Highway Pilot
- Urban Scenarios
- Parking Lot

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**MODULAR**
Integration of algorithms executing at different rates

**EFFICIENT**
Automatic code generation of complex algorithms

**TEAM SYNERGY**
Team collaboration made easy across continents
ADAS/AD Function Development Platform

2018 KIA Soul EV AVL Development Platform

2020 Consumer Electronics Show (CES)
Lv2+ ADAS/AD MBD Process Overview

1. First-principles plant models of the system
2. Develop control algorithms
3. Co-simulate controller and system models
4. Next design iteration

Typical Feature Development Lifecycle

- Start of development
- Feature Concept
- System Design
- Functional Design
- Component level Design
- Software/Hardware Development
- Functional Integration testing
- Feature Assessment
- System Integration Plan
- Functional Integration Plan
- Unit device Test Plan
- Component Verification
- Feature Sign Off
- System Validation
- System Integration Plan
- Functional Integration Plan
- Component Verification
- Feature Sign Off
- End of development

Timeline

Control functions iteration

Component level Design

Timeline

Not Here!
1. First-principles plant models of the system

- AVL deploys various commercial vehicle dynamics tools to provide high-fidelity vehicle and powertrain dynamics within ADAS virtual environments, fully integrated to Simulink for controls development.

**AVL VSM™** provides a high fidelity attribute balancing platform which can be embedded within ADAS environments such as VTD.

**CarSim** and **TruckSim** provides additional sensors and environments for ADAS simulation, to close the loop for controls performance assessment via **AVL-DRIVE Autonomous™**.
1. AVL-DRIVE Autonomous
A tool for the objective assessment

AVL-DRIVE Autonomous™
- Enhances the feedback from simulations with perceived safety, safety and comfort assessment
- Provides consistent development and testing tools on road, test bench and virtual environment
- Enable the reuse of office simulation environment for continuing development phases
- Provides maneuvers for scenario variations development to maximize test coverage

Simulation (VTD) & Road Assessment with AVL-DRIVE Autonomous™ Ratings
Scenario Variations with Simulink/TruckSim (ACC testing)
1. Modeling of other key components

- **Environment Model**
  - Occupancy Grid Representation
  - Drivable Space Identification

- **Decision Making**
  - Driving Scenario Identification
  - Target Maneuver Generation

- **MBD advantage:**
  - **Partnership Open**
2. Develop control libraries

Motion Planning SW development

Structured Motion Planning
- Algorithms
  - Model Predictive Control Optimization & Dynamic Programming for Path & trajectory sample generation and selection
- Data Structure
  - ArrayList to store path and trajectory information

Unstructured Motion Planning
- Algorithms
  - Hybrid A* and Post Optimization
- Data Structure
  - Graphs and Priority Queues (MIN-Heap) for Forward State Generation & Search State Bookkeeping
  - Hash Tables for Motion Primitive Look-Up & Cost Association
2. Develop control libraries

Motion Control SW Development

- Algorithms
  - Longitudinal Control
    - **Feedforward** and **feedback PI** control for throttle and brake
  - Lateral Control
    - **Extended Stanley** method for steering control
2. Develop control libraries

Localization

- Algorithms
  - Extended Kalman Filter

- MBD advantage
  - Rapid control prototyping

3-D positions [m]
3-D velocities [m/s] @ max. 20Hz

3-axis accelerations [m/s²]
3-axis rate gyros [rad/sec]
3-axis attitude angle [rad] @ 100 Hz

Output

- 2-D position [m] (North-East in ENU coordinate)
- 2-D velocity [m/s] (Vehicle XYZ Frame)
- Longitudinal/lateral accelerations [m/s²] (Vehicle XYZ Frame)
- Heading angle [rad] (referenced to North in ENU coordinate)
- Heading rate change [rad/sec]
2. Develop control libraries

Integration – Threading & Parallelization

- Modules implemented as model reference function-call subsystems to enable:
  - Different execution rates
  - Core partitioning on the hardware

- MBD Advantage
  - Hardware platform agnostic
  - Available tools for synchronization and memory configuration to grant successful threading and parallelization

Example of execution timeline on Speedgoat
3. Co-simulate controller and system models

MIL Simulation Results

Static Vehicle Take Over

Dynamic Vehicle Trajectory Prediction and Take Over
3. Co-simulate controller and system models

MIL Simulation Results in Parking Lot
Pose = (x, y, Θ)

Start Pose: x=30, y=25, Θ=15°
Goal Pose : x=83, y=46, Θ=90°

Start Pose: x=10, y=80, Θ=0°
Goal Pose : x=57, y=92, Θ=-90°

Start Pose: x=5, y=20, Θ=90°
Goal Pose : x=78, y=90, Θ=90°

*: A*
O: Hybrid A*
4. Next design iteration

Simulation output used to increase feature maturity resulting in:
- Honed requirements
- Feature performance improvements
- Library iteration

Typical Feature Development Lifecycle

Co-simulate controller and system models
AVL’s Lv2+ ADAS/AD Function Offering Via MathWorks Toolchain (MBD)

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Additional AVL Offerings in ADAS/AD Domain

Typical Feature Development Lifecycle

Start of development

Feature Concept
System Design
Functional Design
Component Level Design
Software/Hardware Development

End of development

Feature Assessment
System Integration Plan
Functional Integration Plan
Unit Device Test Plan
Component Verification

Timeline

AVL VSM™
Precise vehicle dynamics simulation

Sensor Simulation
Models for Radar, Lidar, Camera and Ultrasonic

Environment Simulation
Traffic, road and environment modeling

Test Case Generator
Based on scenarios

Cloud Master
Parallel computing

AVL-DRIVE™
Objective evaluation of Automated Driving (incl. perceived safety)

AVL CAMEO™
Active COT test optimization

AD Controller
e.g. ACC/LKA, AEB, Highway Pilot, Traffic Jam Pilot, Automated Parking
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Thank You

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