Fast-Tracking Advanced Driver Assistance Systems and Autonomous Vehicles Development with Simulation

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Xavier Fornari – Product Manager – ANSYS SBU (xavier.fornari@ansys.com)
Outline

- ANSYS & System Business Unit Overview
- The increasing complexity of car systems
- Digital Simulation
- Model-Based Engineering and Certified Code Generation
ANSYS & System Business Unit Overview
ANSYS: World’s Leading Engineering Software Provider

FOCUSED
This is all we do.
Leading product technologies in all physics areas
Largest development team focused on simulation and embedded software

CAPABLE
2500+ employees
75 locations
40 countries

TRUSTED
96 of the top 100
FORTUNE 500 Industrials
ISO 9001 and NQA-1 certified

PROVEN
Recognized as one of the world’s MOST INNOVATIVE AND FASTEST-GROWING COMPANIES*

LARGEST
3x The size of our nearest competitor

STRONG
45000+ CUSTOMERS in every major industry segment

INDEPENDENT
Long-term financial stability
CAD agnostic
Based on standards

*BusinessWeek, FORTUNE
ANSYS Simulation Platform Overview

Towards a Complete Systems Simulation
The increasing complexity of car systems
Cars: Increasing Complexity

- ECU: > 100
- Software Size: 100 Mi LOC
- Multiple integrated Networks
- Sensor Fusion & Surround Sensing
- Increasing # of Variants
- Etc.
From Advanced Driver Assist Systems to the Self-Driving Vehicle

- Adaptive Cruise Control (ACC)
- Forward Collision Warning (FCW)
- Collision Mitigation Braking (CMB)
- Lane Departure Warning (LDW)
- Blind Spot Warning (BLSW)
- Lane Keeping Assistance (LKA)
- Pedestrian Avoidance (PA)
- Intelligent Headlight Systems (IHS)
- Cooperative Driving Systems (CDS)

- Self-driving is more than a collection of ADAS
  - Huge complexity
- Safety is reinforced
  - Sensors/Actuators must work
  - Software must work

Reference: http://safety.trw.com/autonomous-cars-must-progress-through-these-6-levels-of-automation/0104/
A Car is a Complex System...

- Electronic Control Units
- Safety Requirements
- Electric Drives
- Actuators
- Operational Profiles
- Embedded Software
- Sensors
- Operating Conditions
- Electric Drives
....With Complex Interactions
Nearly every automotive E/E-System is Safety related

• **Electric Drivetrain**
  – Battery Overcharging -> Fire
  – Blocking Wheels -> Rear Crash

• **Autonomous Driving**
  – Misinterpretation of Crossing Situation -> Front Crash

• **Advanced Driver Assistance Systems**
  – Non Recognition of Obstacle -> Accident
  – False-positive Recognition of Obstacle -> Rear Crash

• **Active & Passive Safety Systems**
  – Unintended Airbag Deployment -> Loss of Car Controllability
  – Unintended Braking (by Multi-collision Braking System) -> Rear Crash

• **Connected Car, V2V, V2I**
  – Smart Phone issued Car Move (Car Parking) -> Pedestrian Injury
  – Smart Phone controlled unintended Seat Movement -> Driver Distraction

Source: Land Rover

Source: digitaltrends
For autonomous Driving: Validation and Testing Challenges

Driving to Safety
How Many Miles of Driving Would It Take to Demonstrate Autonomous Vehicle Reliability?

- Autonomous vehicles would have to be driven hundreds of millions of miles and sometimes hundreds of billions of miles to demonstrate their reliability in terms of fatalities and injuries.

Akio Toyoda, President of Toyota @ Paris Auto Show

“It is estimated that some 8.8 billion miles of testing, including simulation, are required”

Image Source: Wikipedia Creative Commons
Cost of ISO 26262

- Cost of activities is **increasing quickly**, starting at ASIL B
- ASIL D is > 200% versus non certified development

Digital Simulation coupled with Model-Based Engineering and Certified Code Generation can answer to the challenge
Digital Simulation
Autonomous driving technology – a control loop

Physical World

Actuators

Sensors

Controllers
Simulation of autonomous vehicle control loop

Drive Scenario Model
Creates a model of the virtual world and animates motions of the test car and other objects in a test drive

- 3D road and landscape model
- 3D models of stationary and moving objects
- Object sensory attributes (e.g. radar reflectivity)
- Object motion definition
- Motion simulation in time domain

 Courtesy: Mechanical Simulation Corp.
Simulation of autonomous vehicle control loop

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Sensor Models
- “Observe” the surroundings in the virtual world of the drive scenario model and output processed sensor signals
- Sensing simulation
- Signal processing
- Radar
- Lidar
- V2X
- GPS
- Ultrasonic Sensors
Simulation of autonomous vehicle control loop

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Signal Proc. & Sensor Fusion
- Identifies objects and driving conditions from sensor data

Control Algorithms and HMI
- Makes main control decisions; Displays critical information and decisions to the driver
- Software Lifecycle, Models Based Development
- Software Testing, Code Generation
- ISO26262, Functional Safety

Sensor Models
- PMD
- Cameras
- Radar
- Lidar
- V2X
- GPS
- Ultrasonic Sensors
Simulation of autonomous vehicle control loop

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Vehicle Dynamics Model
Computes position, velocity and orientation of test vehicle
- Vehicle mechanical model
- Sub-models for vehicle attributes

Vehicle Component Models
Uses actuator inputs and computes response of vehicle sub-systems such as brakes and steering
- 3D models of vehicle components
- Detailed Multiphysics simulation

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ANSYS Autonomous Vehicle Simulation Platform

System Simulation

Control & HMI Software

Functional Safety

Sensor Modeling

Hardware Simulation

Simulate driving scenarios with detailed physics. Virtually test control algorithms, sensor accuracy and vehicle dynamics

Develop ISO 26262 qualified, AUTOSAR compliant control and HMI software with model based development tools

Ensure safety of automated systems by providing state-of-the-art reliability analysis methods, using simulation for verification

Accurately model radars, lidars, V2X communication, GPS antennas, ultrasonic and other sensors with high-fidelity physics

Optimize signal integrity and thermal, structural, electro-magnetic reliability of semiconductors, electronics and mechanical hardware

Integrated development with a common platform ✩ Faster development ✩ Better optimized overall product ✩ Cost economy ✩ Better quality
Simulation of autonomous vehicle control loop

Embedded Control / SW
ABS, speed, obstacle detection

ABS actuators & valve

Head up Display

Radar ROM from 3D

Driving scenario
Simulation of autonomous vehicle control loop
Model-Based Engineering and Certified Code Generation
ISO 26262 Impact on Development Activities

- 4-7 System Design
- 6-6 Specification of software safety requirements
- 6-7 Software architectural design
- 6-8 Software unit design and implementation
- 6-9 Software unit testing
- 6-10 Software integration and testing
- 6-11 Verification of software safety requirements
- 4-8 Item Integration and testing

Traceability, 100% coverage
Reviews of artifacts, results
MBSE and Certified Code Generation

- MBSE helps having **better designs**, easier to review
- **Certified Code Generation**: require Tool Qualification, and **provides important gains**
- **SCADE**: only **COTS developed** following the standards.
ANSYS Systems & Embedded Software Capabilities

- **System & SW Architecture**
- **SW Design**
- **System Requirements**
- **Software Requirements**
- **Automatic code generation**
- **Integration toolbox**
  - Multi-rate / Multi-core

**System Safety**

**System Architecture**

**System Simulation & Digital**

- **Simploter**
- **MiL & PiL testing**

- **System Requirements**
- **Software Requirements**
- **Automatic code generation**
- **Integration toolbox**
  - Multi-rate / Multi-core
Enhanced Autonomous Vehicle Control Loop

Environment

Hardware

Software

- Sensors
- Actuators
- Environment model
- Vehicle position
- Environment model
- Vehicle position

Data

Command

Action
Enhanced Autonomous Vehicle Control Loop Challenges

• Challenges
  − Lack of controllability (no driver) implies high ASIL
  − Difficulty to establish traceability from Machine Learning/Deep Learning models and extremely complex requirements

• A possible solution: the “Command-Monitor” Architecture
  − Safety is controlled by the monitor
  − Monitor is developed using best practices for high-integrity software: MBSE, Safety Analyses, certified code generation
Our Vision To Validate Machine Learning Algorithms

ANSYS Simulation Platform (HFSS, SBR+, Simplorer, HPC and ROMs)

CNN UNDER TEST

Example objective: look for causal relationships between tuning the “focus knob” and the behavior of CNN’s hidden layers.

CNN-based Embedded Software within SCADE
Conclusion
Improving all Development Phases

- Initial system view
  - Early concepts and analysis

- Safety analyses
  - Model-based environment
  - State of the art analyses

- Model-based System Engineering
  - Synchronized with Safety architecture

- Architecture – Design synchronization
  - Dedicated model-based environment for embedded applications
  - ISO-26262 Certified code generation (TCL3 tools)

- Integrated system view
  - Realistic 3D models
  - ROMs
  - Embedded software
  - Performance analysis
  - Interaction analysis

- Functional validation on desktop with interactive simulation/debug
  - Structural coverage (ASIL D)
  - Reuse of tests on target

- Safety support at all steps
  - Traceability of all artefacts

Automatic code generator developed following ISO 26262 standard:
- No need to verify code against specification (design)
- Functional unit testing on code dramatically reduced or suppressed
## Digital Simulation and MBSE Benefits Summary

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<tr>
<th>Product Development and Safety Analysis Process Improvements</th>
<th>Best Practices for:</th>
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<tr>
<td></td>
<td>• Model-Based Systems Engineering</td>
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<td>• System Safety Analysis</td>
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<td>• Integrated Multi-physics and Software Simulation</td>
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<td>• Embedded Controls development</td>
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<th>Development and Safety Analysis Costs Reduction</th>
<th>50%</th>
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<th>Time-to-Market Speed up</th>
<th>2X</th>
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Thanks you!