VSI Labs

The Build Up of Automated Driving

October - 2017
Opening Remarks
Introduction and Background
Customers Solutions
VSI Labs
Some Industry Content
Automated vehicle systems is a very complex endeavor for the traditional auto industry who are pressured to develop solutions and strategy.

AV solutions is a mind boggling mix of disciplines – data sciences, artificial intelligence, robotics, functional safety, etc.

Developers of automated vehicle systems need to understand the eco-system and the technicalities associated with AV development even before they embark on their engineering projects!

VSI provides this level of knowhow to help companies understand the eco-system, the solutions, the development challenges and so on.
Introducing VSI – A New Way to Engage in AV Research

- Established 2014 by Phil Magney
- **Supports R&D & planning departments** with deep insight on AV enabling technologies (eco-system).
- Provides technology roadmaps and is currently involved with major OE and suppliers worldwide.
- Conducts applied research and performs -- **Functional Validation** of HW/SW components or systems.
- VSI is quoted extensively in industry trades and is a regular speaker at key conferences globally. [https://vsi-labs.com/news/](https://vsi-labs.com/news/)
- VSI people are skilled in **contemporary AV technologies** such as PreScan, Simulink, OpenCV, Neural Networks, Python, C++, control theory, robotics (ROS), and Functional Safety.
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The Development of Automated Driving

VSI Labs
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• There is a rush to develop the **AV stack** – the HW/SW elements of automated driving.
• The AV Stack is a massive collection of IP and is further supported by cloud & IoT.
• There is a new round of development platforms – open source, open interface, and SDKs to entice developer activities and build up eco-system partners.
• AV technologies are being targeting by the tech giants (nothing new) – but, they don’t plan on building cars!
• Incremental AV is happening rapidly and in production now... Who will build a better Tesla?
• Meanwhile, Level 4 development is well under way for share mobility platforms... Commercial vehicles operating in urban environments.
# The Build Up of Automated Vehicles

**Platforms**
- Waymo
- Uber
- Lyft
- NuTonomy
- Easy Mile
- Baidu
- Toru Robotics
- Zoox
- ROM Group
- NVIDIA
- NXP
- ZF
- NVIDIA
- Magna
- Continental
- Bosch
- Delphi
- Hitachi
- Renesas
- TTTech
- Intel
- Visteon

**Processing**
- Renesas
- NVIDIA
- Continental
- TDA
- Texas Instruments
- Mitsubishi Electric

**Sensing**
- Bosch
- Continental
- TDA
- TRW
- Velodyne
- LiDAR
- NVIDIA
- NXP

**Data/Connectivity**
- Hitachi
- Renesas
- NXP
- QNX
- GWN

**Mapping**
- TomTom
- HERE
- Google
- MapInfo
- Mitsubishi Electric

**Algorithms**
- Elektrobit
- NVIDIA
- dSPACE
- AMotive
- DeepScale
- AURO
- VECTA

**Security/Safety**
- Bosch
- Delphi
- Continental
- Harman
- Karamba Security
- Argus

**Development Tools**
- Baselabs
- AMotive
- MathWorks
- Mentor Graphics
- Vector
- Synopsys
- Caffe

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Two Approaches to Autonomy – Not a Zero Sum Game!

**Automated Driving**
- Evolution of singular ADAS features
- SAE Levels 1, 2, and 3
- Automated Driving
- Step-by-Step approach
- Existing automotive strategy

**Driverless Cars**
- Driverless Cars
- SAE Levels 4 and 5
- Driverless vehicle
- Requires advanced robotics and AI
- Pursued by tech industry

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SAE levels of autonomous driving

Level 0  No Automation
- Human driver controls the driving environment

Level 1  Driver Assistance
- Human driver controls the driving environment
- Steering and acceleration/deceleration

Level 2  Partial Automation
- Automated driving system controls the driving environment
- Steering and acceleration/deceleration

Level 3  Conditional Automation
- Automated driving system controls the driving environment
- Steering and acceleration/deceleration

Level 4  High Automation
- Automated driving system controls the driving environment
- Steering and acceleration/deceleration

Level 5  Full Automation
- Automated driving system controls the driving environment
- Steering and acceleration/deceleration

*DDT = Dynamic Driving Task

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The Functional Domains of Automation

1. The **perception domain** considers all environment sensors such as camera, radar, LiDAR, ultrasonic, as well as other sensors such as inertia, positioning, throttle position, steering angle etc.
   • **Fusion of sensor data** can be done with objects (complete sensors modules such as Mobileye) or can be done with RAW data or a combination.

2. The **localization domain** couples knowledge (ground truth) to its environmental model in order to understand its relative position against the real world.

3. The **behavior domain** is where decision are made with respect to motion control.
   • Active safety systems or L2 automation rely on traditional deterministic algorithms but higher levels of automation will rely on probabilistic algorithms (such as AI) to better predict maneuvers.

4. The **safety domain** (aka Safety Monitor) encases the system as a whole and validates all outputs.
Automation Pipeline

**Image Sensors**
- Camera(s)
- Thermal
- Scanning LiDAR

**Ranging Sensors**
- Radar
- Flash LiDAR
- Ultrasonic

**Map Data**
- Metadata
- Lane level detail
- Dynamic content

**Localize & Plan**
- Sensor fusion
- Grid fusion
- Precise localization
- Path planning

**Behavior**
- Decision making
- Trajectory planning
- Maneuver planning
- Fail safe plan

**Control Algorithms**
- PID Control
- Control loop
- State machine
- MPC Control

**Wheel speed sensor**  **Inertia measurement**

**Longitudinal Control**
- Wheel speed sensor
- Inertia measurement

**Steering Angle**  **Throttle position**

**Latitudinal Control**

The AV Stack
Autonomous Vehicle Domain

Application Development Platforms

Run Time SW Components & Basic SW Services

Perception
- ASIC/FPGA
- GPU Accelerators
- SIMD Memory
- Sensors
- Detectors/CNNs

Localize & Plan
- Data Path Processing
- DDR Memory
- Localization datasets
- Inertia Measurement
- GNSS

Decision / Behavior
- Motion Engine
- ECC Memory
- Behavior Modules
- Arbitration
- Predictors/RNNs

Control
- Lockstep Processor
- DDR Memory
- Safety Monitors
- Fail Safe Fallback
- By-Wire Controllers

Connectivity & I/O
- RF Processors
- Network switches
- Deterministic Bus
- NAND/NOR Memory
- Data Recording

Automation IT Stack – “The AV Stack”
The IoT Stack -- How the Cloud will Manage Autonomous Vehicles

Data Collection
• Record sensor data and uploading the data to the cloud
• Record sensor inputs against human driver output (shadow mode)
• Collect raw data for training the AI-based algorithms
• Collect performance and diagnostic information
• Capture edge cases
• Record objects for localization assets
• Record dynamic objects – traffic flow, pot holes, road condition, etc.

Data Distribution
• AV Software updates – version control
• Firmware updates to distributed ECU systems
• Updated localization assets – maps and supplemental
• Distributing new algorithms
• Distributing updated fail safe and fall back instructions
• Distribute real time road/traffic conditional information

2. Automated vehicle systems must be defined with one or more **Operational Design Domains (ODD)**.

3. A SAE Level 2, 3 or 4 vehicle could have one or multiple ODDs – e.g. geo-fenced urban, divided highways, automated parking, traffic jam assist, etc.

4. A L5 vehicle has only one ODD as it can (in theory) work anywhere!

5. AVs should be developed, tested and validated against all sceneries that could happen within the ODDs.

6. Each scenario is backed with a **Object and Event Detection and Response (OEDR)** – details how the AV will handle expected and unexpected events.

7. Each scenario must have a **fall back** plan... what to do when system fails.
Developing Automated Vehicles – Validation and Testing

• **Simulation** -- allows for the thorough testing of complex systems.
  • These environmental models allow you to define the actors, sensor packages, conditions and scenes

• **Test Tracks** -- Test Tracks allow the creation of some unique scenarios and apply real physics.
  • However, even with excellent test track design and availability, it is impossible to fully test complex systems

• **Field Tests/Real World Data Collection** -- It is important to drive as many miles as possible.
  • Unfortunately, field tests cannot provide enough scenarios (edge cases) to fully qualify a complex system.

• **Artificial Intelligence** – You can use real data or simulated data to train a the Neural Network.
  • To validate, you can examine the layers to see what activates the network... isolate the problems... adjust the weights in the inference model, then test again to check the outcomes.
It is recommended to utilize **detailed simulations** to develop the systems, **test-track tests** to validate components and full-vehicles, and **field tests** to verify the real-life system robustness, whose results can be utilized to train a **neural network** for further testing and simulating of a specific system.
Developing Automated Vehicles – Fleet Testing Using *Shadow Mode*

**What is it?**
- The AV Engine runs in **shadow mode** only – for data collection and evaluation
- Actual AV output commands are recorded alongside real driver inputs
- Once new scenarios are captured, the network is trained and validated, the new feature is then enabled via software OTA

**Purpose**
- Supplements testing and validation
- Discover new edge cases
- Evaluate machine performance
- Examine human performance vs. machine performance

Tesla is Running Shadow Mode to test and refine features, even before making them available.
Closing Remarks

• Automation = Safety
• Incremental automation is happening now.
• Incremental automation is a big selling factor over the next 10 + years before fleet automation starts to dent private ownership.
• Fleet automation in a few cities in a few years. But within a highly constrained operational domain.
• The balance of power is changing (no longer dominated by big auto!)
• The eco systems of new mobility has many new constituents!
• Mobility as a Service (MaaS) becomes the outcome of highly automated vehicles.
• Infrastructure requirements still an open question in the near term.
Enjoy the ride!