Connected vehicles
- challenges and opportunities

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Can you spot the car?
5th Avenue, New York, 1900

Can you spot the car?
5th Avenue, New York, 1913

Can you spot the horse?
1875 Internal combustion engine (Nikolaus Otto)
Automotive Innovation Timeline

1875 Internal combustion engine (Nikolaus Otto)

1885 Benz Patent Motor Car

1900

1950

2000
Automotive Innovation Timeline

1875 Internal combustion engine (Nikolaus Otto)

1885 Benz Patent Motor Car

1886 Daimler Four Wheel Car

1900

1950

2000
Automotive Innovation Timeline

1875 Internal combustion engine (Nikolaus Otto)

1885 Benz Patent Motor Car

1886 Daimler Four Wheel Car

1886 Accelerator pedal, battery ignition, spark plug, ...

1875 Internal combustion engine (Nikolaus Otto)
Automotive Innovation Timeline

- 1875 Internal combustion engine (Nikolaus Otto)
- 1885 Benz Patent Motor Car
- 1886 Daimler Four Wheel Car
- 1886 Accelerator pedal, battery ignition, spark plug, ...
- 1913 Ford Model T

1875 Internal combustion engine (Nikolaus Otto)
Automotive Innovation Timeline

1875 Internal combustion engine (Nikolaus Otto)

1885 Benz Patent Motor Car

1886 Daimler Four Wheel Car

1886 Accelerator pedal, battery ignition, spark plug, ...

1913 Ford Model T

Then nothing happens for 100 years...

2006 My Car
Automotive Innovation Timeline

- 1875 Internal combustion engine (Nikolaus Otto)
- 1885 Benz Patent Motor Car
- 1886 Daimler Four Wheel Car
- 1886 Accelerator pedal, battery ignition, spark plug, ...
- 1913 Ford Model T
- 1900
- 1950
- 2000

Connectivity
Telematics
ADAS
Autonomous driving
e-propulsion
e-services
voice interfaces

Until now!
5th Avenue, New York, 2018
Take-home message #1

• After a 100 year hiatus there is once again serious innovation in the automotive industry
Size of software in vehicles
Percentage of repair-shop visits due to software related faults
Take home message #2

Cars are turning into computers on wheels
The connected vehicle

• ~100 Electronic Control Units (ECU) in a modern car
• In-vehicle networks interconnecting ECUs
• Connectivity and Telematics enable remote access to data from ECUs (and other in-vehicle data sources)
• New e-services and new business models appearing
Opportunities

- Enabling **new products features** based on connectivity and **new aftermarket services**
- **Continuous deployment** of in-vehicle software
- Supporting **knowledge-driven product development**
- **Shortening development cycles** by providing ubiquitous access to reliable data from products in use
- **Improving product quality** by finding faults earlier through **online diagnostics and analytics** services
- Supporting **intelligent transportation systems (ITS)** by sharing data
- Promoting **data-driven innovation**
Connectivity as an enabler for new automotive aftermarket services

- Connected collaborative active safety systems
- Remote diagnostics and prognostics
- Predictive / preventive service and maintenance
- ADAS and Autonomous Driving support
- Connected infotainment services
- Continuous deployment of software
- New business offerings based on car-sharing, service-based transportation, etc.
Connected collaborative active safety

Volvo Slippery Road Alert System
Autonomous driving

- Need for low latency V2V and V2I communication
- Challenging processing and communication of multimedia data (video, radar, lidar, ...)
- Sophisticated development tools for design, test, verification and experimentation are needed by automotive OEMs and component developers
Overtaking support based on v2v video

live video stream

Camera

IHU live video display

RETINA
360 video for ADAS and traffic monitoring

Traffic monitoring center

Roadside 360 video beacon

In-vehicle live video display
Overtaking support based on v2v video

Camera

live video stream

IHU live video display
Remotely controlled vehicle

live video stream

Internet

5G

(Semi-)autonomous vehicle
Take-home message #3

- The sky is the limit for new services based on connectivity in the automotive industry
Connectivity, Telematics and Analytics supporting knowledge-driven product development

- Collect and analyze data from connected vehicles for use in product development
- Sensor signals, diagnostics data, user behavior and user experience data
- Both pre-production test vehicles and customer vehicles
Automotive Telematics and Analytics enabling knowledge-driven product development

Capture
Connectivity, Telematics, Diagnostics

Analyze
Big Data analytics, Data mining, Cloud computing

Decide
Knowledge bases, data sharing, collaboration

Other data sources

Analytics Framework

Raw data

In-vehicle data sources

Knowledge

Collaboration, decision-making

Collaboration, decision-making
Automotive telematics for product development, testing, validation and fleet management

Capture
Connectivity, Telematics, Diagnostics

Vehicle fleet

Internet

3G/4G/WLAN

WICE server

Measurement data storage

Analytics server

Web front-end

Users

In-vehicle Data Capture and Wireless Communication Units
Data analytics and visualization

- Aggregates data from fleets of vehicles, analyzes and visualizes results
- Web-based front end integrating analytics and visualization components with Telematics system
- Main focus on time series data analytics & statistics
- Data driven
- Extensible
Collaboration and decision-making based on analyzed data

Decide
Knowledge bases, data sharing, collaboration

Wow! Interesting. What do you say Sara?

That's fantastic!

Take a look at this!
Data-driven analytics approach

- Stakeholder
- Identify need for improved knowledge
  - Design measurement task
    - Map measurement assignment to vehicles
    - Capture data from fleet of vehicles
  - Design analytics task
    - Configure and set-up analytics framework
    - Execute analytics assignment
  - Knowledge base
  - Analysis results
Subjective data capture and analysis

Combined analysis of subjective and objective data

Survey design tool

Please rate your driving experience

Good
Bad

Objective measurement data

Subjective customer data
Subjective Data Capture Smartphone App
Subjective Data Capture

- App can capture data using text-to-speech and voice recognition
Need for new knowledge identified

Design subjective & objective data capture tasks

Capture subjective & objective data

Analyze subjective & objective data

Continuous deployment (in test vehicle fleets)

Improve vehicular software based on analyses and ML

Rapid prototyping framework

WICE telematics & remote software download

Data capture configuration and survey design tools

How do customers experience our products?

How are the vehicular subsystems performing?

Product developer

Cloud-based analytics framework and methodology

External data sources

Smartphone app

WICE in-vehicle data logging & telematics

ML training data sets

Rapid prototyping framework

ML training data sets

WICE in-vehicle data logging & telematics

Smartphone app

How do customers experience our products?

How are the vehicular subsystems performing?

Product developer
Continuous Deployment OTA

ECU software development → Integration tests → RSWDL OTA → Roll-out loop → Measurement data analysis and validation

ECU Software and Parameters
Measurement data
Rapid Prototyping of connected Automotive Services

- Ideation and conception
- Evaluate, redesign, improve
- Concept sound
- Rapid prototyping
- Aggregate, analyze, learn
- Data Capture, subjective & objective
- Testing, experimentation, PoC
- Productify
- Monitor, management
- ML training data sets
- Cloud-based data processing and analytics framework
- WICE in-vehicle data logging & telematics
- CAN, FlexRay, LIN
- Dashboard
- WICE telematics, RP platform & remote software download
- Connected test vehicle fleet
- I have an idea for a new in-vehicle (connected) service or function
- I need to experiment to gain more knowledge and do a PoC
Automotive testing
Take-home message #4

• To stay competitive in the automotive market, product development processes must be both **agile** and **knowledge-based**, promoting **innovation**, while retaining the traditional attention to quality, safety, and economies of scale.
Challenges

• Volume and complexity of data increases
  – How do we design the technological framework supporting capture, analysis and decision-making in a way that is scalable to large numbers of connected vehicles and high data volumes?

• Security and safety

• Privacy preservation

• Product development process affected
## Estimated Data Volume

<table>
<thead>
<tr>
<th>Application</th>
<th>Fleet</th>
<th>Per day</th>
<th>Per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAN bus signal monitoring</td>
<td>Customer</td>
<td>560 TB</td>
<td>206 PB</td>
</tr>
<tr>
<td>CAN bus signal monitoring</td>
<td>Test</td>
<td>4.5 TB</td>
<td>1.6 PB</td>
</tr>
<tr>
<td>Remote Diagnostic Read-Out</td>
<td>Customer</td>
<td>100 GB</td>
<td>36 TB</td>
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<tr>
<td>Remote Diagnostic Read-Out</td>
<td>Test</td>
<td>10 GB</td>
<td>3.6 TB</td>
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<tr>
<td>State-of-Health</td>
<td>Customer</td>
<td>1 GB</td>
<td>365 GB</td>
</tr>
<tr>
<td>State-of-Health</td>
<td>Test</td>
<td>100 MB</td>
<td>36 GB</td>
</tr>
<tr>
<td>Video / radar / lidar</td>
<td>Test</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Take-home message #5

• Automotive data processing systems must be scalable to large volumes of data.
Security & Safety

• Safety has always been a major concern in automotive engineering
• Vehicles were not originally designed to be connected
Traditional Electrical Vehicle Architecture
Traditional Electrical Vehicle Architecture

Data is broadcast in cleartext on the communication bus
Traditional Electrical Vehicle Architecture with Connectivity

- ECU
- ECU
- ECU
- TEM
- CAN bus
- Actuator
- Telematics / Connectivity unit
- Uplink
Security problem!

Stolen Data

Malicious code or security hole

Uplink

Telematics / Connectivity unit

CAN bus

Actuator

Cleartext data

ECU

ECU

ECU

TEM

ECU

ECU

ECU
Safety problem!

- Malicious code or security hole
- Uplink
- Telematics / Connectivity unit
- CAN bus
- Actuator
- Safety-compromising message injection
(Simplistic) Countermeasure
Traditional Electrical Vehicle Architecture
(slightly more advanced)

Backbone
e.g. FlexRay

GW
ECU
ECU
ECU
Actuator
CAN segment

GW
ECU
ECU
ECU

GW
ECU
ECU
ECU

GW
ECU
ECU
ECU

Actuator
CAN segment

Actuator
Security / Safety by isolation

- Firewall / Access Control
  - Telematics / Connectivity unit

- Backbone e.g. FlexRay
  - Non-critical CAN segment
    - ECU
    - ECU
    - ECU
    - ECU
    - ECU
    - Actuator

- Non-critical CAN segment (e.g. Comfort)
  - ECU
  - ECU
  - ECU
  - Actuator

- Safety critical CAN segment (e.g. Propulsion)
  - ECU
  - ECU
  - ECU
  - Actuator
Security / Safety by even more isolation

- Firewall / Access Control
- Telematics / Connectivity unit
- Non-critical CAN segment (e.g. Comfort)
- Non-critical CAN segment (e.g. Comfort)
- Safety critical CAN segment (e.g. Propulsion)

Backbone e.g. FlexRay

GW

ECU

TEM

Uplink

FW

Actuator

ECU

Actuator

ECU

Actuator

ECU

Actuator
Security / Safety by isolation (back to square one)

Backbone e.g. FlexRay

Non-critical CAN segment (e.g. Comfort)

Safety critical CAN segment (e.g. Propulsion)
Next generation protections

• Security by design
• Safety by Isolation
• Encryption of in-vehicle data communication
• Intrusion detection systems
• Secure operating systems
Take home message #6

• Balance between security measures and agile development / innovation / competitiveness
Privacy

• When collecting large volumes of data from vehicles, users’ privacy must be respected
• Incentives are needed for contributing user experience data
• Anonymisation and Pseudonomisation techniques are inherently problematic
• One approach is to use *Differential Privacy*
  – Noise is added to captured data in a controlled way, so that it cancels out at analysis stage

Summary and Conclusions

• After a 100 years, there is again serious innovation in the automotive industry
  – It is happening now. Let’s not screw it up!
• Cars are turning into computers on wheels
  – Innovation happens in software development. Focus must be on that.
  – Connectivity leads to Big Data
• The sky is the limit for connected automotive services
  – Many new applications and huge benefits
• Competitiveness requires agile development
  – Connectivity & Big Data keys both for new services and agile development
  – Technology platforms must be designed for scalability and flexibility
• Balance between security measures and agile development
  – Security & safety by design
• Privacy mechanisms needed
  – Anonymisation / pseudonimisation often not good enough
• Many unexplored opportunities for cross-sectoral synergies (e.g. between automotive sector and life sciences)
Thank you!