Enabling Continuous Road Monitoring Applications using Connected Vehicle Data

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 dusk road with mountains in the background
What is a Connected Vehicle?
Connected Vehicle Ecosystem
Vehicle Electronics and Sensors

- Rear-Passenger Flat-Panel Displays
- Wheel Sensors
- GPS Navigation
- DVD Player
- LED Lamp Cluster
- Head-Up Displays
- Dashboard-Instrument Cluster
- Telematics System
- Climate Control
- Windshield Wipers
- Radar Sensor
- Transmission Control
- Collision Avoidance
- Adaptive Cruise Control
- HID Headlamp
- Memory Seat/Mirror/Steer
- Airbag Control and Satellite Crash Sensors
- Active Steering
- Body Control
- Suspension Control
- Power Windows
- Remote Keyless Entry
- Seat Massage/HVAC
- Adaptive Brake Lights
- Parking Sensors
- Rear-View Camera
- Battery Management
- Power Seats
- Throttle Control
- Engine Control Unit
- Folding Door Mirrors
- Electrochromic Rear-View Mirrors
- Car Radio
- Antilock-Braking System/Electronic-Stability Program
- Tire-Pressure-Monitoring System (TPMS)
Vehicle Electronics and Sensors

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Data is an asset that enables innovation in many areas of our business.

Crowd sensing is a paradigm where multiple vehicles sense the surrounding environment and communicate their perceptions to the cloud.

Insights are created based on aggregated data.

Enables customer features, system learnings and new business opportunities.
Future vehicles will be substantial producers and consumers of data.

Learning model will increase environmental awareness and improve customer experience.

**PRODUCE**
- Telemetry
- Imagery
- Health Status
- Environmental & Road Sensing

**CONSUME**
- Navigation Maps
- HD Maps
- Connected Infrastructure / IoT
- Commands / Instructions
- Intelligence (traffic, algorithms)
- Multimedia / AR

**SHARE**
- Sensing
- Path Plan
- Coordination Plan

Vehicles as Producers and Consumers of Data
Creating Roadway Insights from Vehicle Data

Sample Applications

- Map
  - Speed limits
  - Stop Signs
- Traffic
  - Flow estimation
  - Hotspots
- Construction
  - Road closures
  - Lane closures
- Weather
  - Heavy rain
  - Snow
  - Fog

- Road Condition
  - Potholes
  - Roughness
  - Slippery Surface

Detected Event

Hazard Notification
Road Hazard Notifications

**Value:**
- Improves customer experience by increasing awareness of surrounding environment
- Road Sensing features monitor relevant vehicle data signals and makes a determination that a potential hazard may exist
- Information consensus performed in cloud to create high confidence insight

<table>
<thead>
<tr>
<th>Use Case</th>
<th>Description</th>
<th>Example Inputs</th>
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</thead>
<tbody>
<tr>
<td>Road Hazard</td>
<td>• Slippery road conditions</td>
<td>• Traction control</td>
</tr>
<tr>
<td></td>
<td>• Potholes</td>
<td>• Suspension sensor</td>
</tr>
<tr>
<td>Severe Weather</td>
<td>• Heavy Rain</td>
<td>• Wiper status</td>
</tr>
<tr>
<td></td>
<td>• Snow, Fog</td>
<td>• Temperature/humidity</td>
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<tr>
<td>Traffic Anomaly</td>
<td>• Roadway congestion</td>
<td>• Vehicle Speed</td>
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<td></td>
<td>• Backups at fork or exit locations</td>
<td>• Posted Speed Limit</td>
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<tr>
<td></td>
<td>• Accidents, construction, etc.</td>
<td>• Traffic flow, Road Class</td>
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</tbody>
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Road Hazard Notifications

**Experience:**

- Customer is informed of relevant hazards in their path
Severe Weather Detection Logic

Example detection algorithm

Wipers Active?

Estimate severity based on setting

Outside Air Temperature > 32°F

Confidence

Rain

Front Fog Lamp Active

Confidence

Snow

Rear Fog Lamp Active

Fog

OR
Data Collection

We deploy data collection tasks to connected vehicle fleet

Configuration, task development and data analytics

Device for feature development
Road Surface Detection using Wheel Speed Sensors

• Used by vehicles for speed indication, stability control and anti-lock braking system features
• Also used to support engine misfire diagnostics by monitoring engine speed oscillations
• Road surfaces may cause oscillating torque on the drive wheels which affects engine speed in a similar way as a true misfire
• An onboard algorithm differentiates true misfires from engine speed oscillations caused by the road surface
• There are two sources of road induced wheel speed oscillations:
  – Bumps such as potholes
  – Drive wheels slipping and hopping as if they are on slippery roads.
Road Surface Detection using Damping Systems

• Used in many luxury vehicles to improve ride comfort by modulating the suspension system in response to the sensed pavement conditions
• Magnetorheological fluid is employed inside shock absorbers to dampen rough road encounters by intelligently actuating the system using electric current
• The inputs to the system are the individual wheel displacement readings whose movements are referenced against the vehicle chassis
• By accumulating these displacement values over a specified distance, an estimated road roughness level can be determined.
Data collection at VTTI Smart Road using single GM production vehicle

Each pavement section was driven 5 times at speeds of 20, 40 and 60 mph

Results were compared to 2017 Rodeo event and SURPRO reference profiler
Joint data collection between ARA using their reference profilers and 3 of our production vehicles

The production vehicles followed the survey vehicle in the same lane

Data collection was performed at the speed limit for local roads and at a maximum of 60 mph on expressways
Summary

- Road safety and road condition are important to vehicle owners and pavement management professionals.
- Connected vehicles enable the communication of numerous roadway characteristics to inform drivers about potentially hazardous conditions.
- Underlying data that enables these features could also provide timely pavement condition data to improve the overall health of the road network.
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