Challenges and Opportunities in Connected Vehicles

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Agenda

• Automotive Future
• Vehicle Health Management
• Conclusion
The world is evolving...
GLOBAL YOUTH

• In 2030, 37% of the world’s population will be under the age of 25 (over 3.1 billion)

• Significantly lower percentage of those aged 16-30 have driver’s licenses compared to 30 years ago

• A study of global youth revealed a common set of values: family, friends, money/status, education, travel, stability, and freedom
By 2030, countries with large populations ages 65+ include:

- Japan 38%
- Germany 33%
- Italy 32%
- Canada 27%
- UK 26%
- U.S. 24%

Aging isn’t what it used to be... “mature” citizens more active, healthier, and live longer than ever before
In 1950, two-thirds of the world’s population lived in rural areas... by 2030, almost two-thirds will live in cities.

There are 28 megacities today with populations exceeding 10 million.

Megacities: Tokyo (38M), Delhi (25M), Shanghai (23M), Mexico City, Mumbai and Sao Paulo (21M).
Mobile-cellular subscriptions approaching 7B, the number of people on the earth

3B use the Internet

Facebook has over 1.4 billion active users globally; 85% are mobile users

90% of the world’s data has been created in the last two years – 2.5 quintillion bytes of data created every day!
The automotive industry is evolving.
So is GM ...
MAVEN CAR-SHARING SERVICE

• GM’s new car-sharing service
• Provide customers access to highly personalized, on-demand services.
• Initially launching at U-Michigan, Ann Arbor
• Expanding to Chicago, Boston and Washington DC
GM-LYFT STRATEGIC ALLIANCE

- Integrated network of on-demand autonomous vehicles in U.S.
- GM preferred provider at Lyft rental hubs
- Connectivity through OnStar for richer ride-sharing experience
- With Maven, Lyft alliance, and OnStar, GM is uniquely positioned in car-sharing space
GM ROADMAP TO AUTOMATED DRIVING

Increasing Capability

Today

Driver Info & Alerts (No Control)

Emergency Intervention (Limited Control)

Limited On-Demand Automation (Monitored Control)

SuperCruise Concept

Today's Driver Assist Package

Complex On-Demand Automation (Transferred Control)

Autonomous Driving (Chauffeured Driving)

TECHNOLOGY ENABLERS:

- Perception and Algorithms
- Integrated Sensing with Maps, GPS, V2X
- Driver State Knowledge
Agenda

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• Everything wears out over time

• Customer’s life is disrupted, when his/her vehicle needs repair unexpectedly

• The solution - Vehicle Health Management (VHM)
  • Alert before failure happens
  • Transform an emergency repair to planned maintenance
  • Enhance ownership experience - a delight to customers

• Introducing OnStar™ Proactive Alerts - a new customer care service
Where are we today on OnStar™ Proactive Alerts?

• Launched on
  • 2016 Chevrolet Equinox
  • 2016 Chevrolet Tahoe
  • 2016 Chevrolet Suburban
  • 2016 Chevrolet Corvette
  • 2016 Chevrolet Silverado
  • 2016 GMC Terrain
  • 2016 GMC Yukon
  • 2016 GMC Sierra
  • 2016 Cadillac Escalade

• Will be extended to more GM vehicle programs over time

• Currently cover three critical components
  • battery, starter, fuel pump
CHEVROLET: SOLVING ISSUES BEFORE THEY HAPPEN

OnStar Proactive Alerts predict when certain components need attention.

VEHICLE DATA TRANSMITTED

IN-VEHICLE MONITORING

STARTER MOTOR

FUEL PUMP

BATTERY

DIAGNOSTICS + PROGNOSTICS

REAL-TIME NOTIFICATION

TEXT

EMAIL

IN-VEHICLE

HOW IT WORKS WITH YOUR BATTERY

VEHICLE BATTERY

BATTERY CONDITIONS SENT

LOW BATTERY PREDICTED

ALERT SENT

ISSUE AVOIDED
How did we get here?

• The challenges
  • Prediction uncertainties due to many impacting factors:
    • usage variations, part to part variations, environmental variations
  • Low false positive and low false negative

• The opportunities
  • Wireless communication
  • Onboard sensor
  • Cloud computing

• The approach
  • Combination of physical model and big data
Physical-model based algorithm generation

- Study failure modes and model physics of failure
- Identify fault signatures and failure precursors
- Estimate model parameters
- Validate concept on benches and test vehicles

Lead Acid Battery
(Plate Surface Scanning Electron Microscopy)

Electric Motor

Equivalent thermal circuit model battery

Equivalent electrical circuit model for battery

Particle filter based battery life estimation
Big-data based algorithm refinement and calibration

- Correlate field data from 1,000,000+ vehicles with warranty analysis and engineering assessment
- Refine failure precursors to address corner cases
- Iteratively calibrate algorithm parameters

Results from Kernel-SVM-based feature ranking

Membership Function for Fuzzy decision tree
A Validation Case Study

![Graph showing data points and annotations with dates and actions]

- **Rho_c**
  - Dates: 06/15, 08/04, 09/23, 11/12, 01/01, 02/20, 04/11
  - Values: 0, 20, 40, 60, 80

- **Replacement Date**

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GM’s Prognostics Press Release @CES 1/4/15

Chevrolet Opens New Chapter for Driver Assurance
Customers will soon drive vehicles that can predict future service needs

DETROIT – Chevrolet is using advanced connected vehicle technology to give customers an unprecedented level of assurance in their vehicles later this year. This industry-leading prognostic technology can predict and notify drivers when certain components need attention – in many cases before vehicle performance is impacted.

The predictive technology monitors the battery, starter motor and fuel pump, all critical to starting and keeping a vehicle running. Additional vehicle parts and components are expected to be added in future model years.

"This is a new chapter in our pursuit to provide customers with convenience and the best overall service in the industry," said Alicia Boler-Davis, General Motors senior vice president, Global Connected Customer Experience. "Using our innovative OnStar 4G LTE connectivity platform, we can actively monitor vehicle component health and notify our customers if covered vehicle components need attention. Nobody else in the industry is offering this.

Building on the 15-year history of connected vehicle technology through OnStar, the prognostic service relies on OnStar's secure servers and proprietary algorithms to assess whether certain conditions could impact vehicle performance. When indicated, notifications are sent to the customer via email, text message, in-vehicle alerts or through the OnStar RemoteLink smartphone app.

This service is expected to be available on select 2016 Chevrolet Equinox, Tahoe, Suburban, Corvette, Silverado and Silverado HD models equipped with certain powertrains, followed by more Chevrolet vehicles throughout the 2016 model year.

Prognostic capability is the latest advancement in a suite of services that will keep Chevrolet customers informed from the first day of ownership through many years into the future.
Chevrolet Now Offers Customers Ability to ‘See’ the Future 
Industry-first OnStar Proactive Alerts set to redefine routine maintenance

DETOUR – What if the company that built your car or truck could warn you about a potential issue before you were stranded on the side of the road? Chevrolet is the only automaker to offer this predictive technology with a new industry-first OnStar service called Proactive Alerts.

Similar to how Boeing 787s can send in-flight messages to ground crews alerting them of parts needing diagnosis and inspection before the plane arrives, Chevrolet takes the guesswork out of certain types of car trouble, predicting problems before they happen and relegating potential roadside breakdowns into routine maintenance. Could the end of the dreaded “check engine” light be next?

Owners of the 2016 Chevy Silverado, Tahoe, Suburban, Corvette and Equinox can now opt-in for OnStar Proactive Alerts, which monitor the health of the vehicle’s starter motor, fuel pump and 12-volt battery. If one of these components is wearing out or if certain faults are detected, OnStar will notify drivers through in-vehicle notifications, and an email or text message based on customer preference.

“Chevrolet already offers the most dependable, longest-lasting full-size pickups on the road, and now we are taking an important step towards the day when you will never be stranded or have certain unexpected repairs on your vehicle,” said Steve Holland, chief technologist for Vehicle Health Management at General Motors.

Predicting the future health of a vehicle component requires sophisticated systems analyzing and refining billions of pieces of data to isolate problems and determine the likelihood of a developing issue. Proactive Alerts works by collecting a small batch of data each time the vehicle is started and monitoring it on an ongoing basis. This enables identification of vehicles that may have an affected part, significantly reducing the number of customers inconvenienced by a potential repair.

“Accuracy is the key to our prediction algorithms,” Holland said. “We want to be able to tell dealer service departments so they can spend less time testing for a condition we have already diagnosed. They can replace the necessary part quicker and minimize the amount of time a customer’s vehicle is at the dealership.”

Proactive Alerts is offered with all OnStar service plans on eligible models, including the OnStar Basic Plan that comes standard for five years on new Chevrolet vehicles. In the future, plans are in place for Proactive Alerts to monitor additional vehicle components and expand to other Chevrolet models.

Of the components for which Proactive Alerts is initially offered, customers most likely would get an alert about their 12-volt battery. A typical lead-acid battery can lose 3 percent of its charge per month, but a low state of charge may require nothing more than the customer going for a drive to recharge the battery—instead of unnecessarily replacing it. However, Proactive Alerts also can spot short circuits and high resistance that can result in premature battery failure.

“A few companies are doing limited in-vehicle diagnostics, but none have yet demonstrated the capability of accurately predicting a component’s life expectancy,” said Paul Krajewski, director of the Vehicle Systems Laboratory in General Motors R&D. “As we keep expanding the parts of the vehicle we cover, we hope to continuously enhance our customers’ experience, saving them time and money.”
We are not done yet. Actually, the journey just started …

Electronic Explosion
The VHM Approach Revisited

1. Identify failure modes
2. Identify precursors and impact factors of failures
3. Develop prognostics algorithms
4. Calibrate algorithm parameters
5. Evaluate the performance
6. Go to 1

Can we automate or semi-automate the steps?
• Failure precursor identification
• Algorithm adaptation with limited number of fault instances
• Automatic calibration
• Performance evaluation with automatic labeling
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Intelligent Transportation in the next decade (2025)

- Automated Highway Driving
- Partial / Full Urban Driving
- Extensive V2V (and V2P) capability
- Acceleration of Intelligent Infrastructure
- High-Volume / High-Speed Integrated Connectivity
- Efficiency / Electrification
- Shared Mobility