Fuel Economy Optimization with Dynamic Skip Fire in a Connected and Automated Vehicle

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**Technical Achievement**

Demonstrated multi-horizon VD&PT optimization algorithm that achieves 20%+ fuel economy improvement on a light-duty vehicle, integrating look-ahead control, mild hybridization, and advanced cylinder deactivation.

**T2M Achievement**

Intelligent Driving suite of technologies for implementation on L0 and L1 applications and a key partnership with commercial mapping provider offers a clear path for OEM engagement.

Synergistic Integration of CAV Intelligence and Advanced Powertrain Control

Fed. funding: $5.0M

Length 36 mo.
Technical Accomplishments

• Fuel-optimal, look-ahead VD&PT control optimizes 48V mHEV powertrain with Dynamic Skip Fire (advanced cylinder deactivation);
• Multi-horizon (long-term/short-term) optimization is solved using Approximate Dynamic Programming (ADP) for Eco-Driving;
• Pass-in-Green environment (PiG-e) enables Eco-Approach and Departure (EAD) functionality at signalized intersections.
Tech-to-Market Accomplishments

• Outreach activities
  • Customer meetings in US, Europe and China pursuing co-development projects
  • Two additional Intelligent Driving vehicles built outside NEXTCAR funding allow ride-and-drive demonstrations of L0 and L1 capability
  • Ongoing TomTom co-development couples Intelligent Driving functionality with TomTom ADAS maps
  • Half-day meeting with EPA technical staff exploring off-cycle CO₂ credits

• Next steps
  • External funding: potential follow-on ARPA-E funding offers opportunity for further development
  • Internal funding: Delphi Technologies and BorgWarner brainstorming potential future development activities
  • OEM direct engagement important for future projects

• Rollout strategy and timeline
  • L0 and L1 Intelligent Driving applications available for further development
  • TomTom ADAS maps offer a strong platform for implementation
  • 2023+ production implementation possible: direct OEM involvement essential to accelerate path-to-production
## Final Efficiency Breakdown Table

- **Baseline for comparison is velocity profile generated via Enhanced Driver Model (EDM), calibrated to match travel time in reference condition;**
- **Test Results** from TRC data from reconstructed routes (Central Ohio region);
- **Simulation Results** obtained via Monte Carlo simulations, over varying routes and randomized SPaT sequences (5400 scenarios).

<table>
<thead>
<tr>
<th>NEXTCAR Technology</th>
<th>Energy Efficiency Improvement (range)</th>
<th>Trip time penalty (if applicable)</th>
<th>Reference (publication)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic Skip Fire (DSF) Optimization</td>
<td>4% - 6% (Simulations) 2% - 4% (Test Results)</td>
<td>&lt;0.5%</td>
<td>[2, 3]</td>
</tr>
<tr>
<td>Eco-Driving and 48V mHEV Powertrain Control Optimization</td>
<td>11% - 21% (Simulations) 15% - 23% (Test Results)</td>
<td>N/A</td>
<td>[1, 3]</td>
</tr>
<tr>
<td>Eco-Approach and Departure Optimization</td>
<td>5% - 10% (Simulations)</td>
<td>2% - 4% Improvement</td>
<td></td>
</tr>
<tr>
<td><strong>Integrated System Energy Benefits</strong></td>
<td>16% - 23%</td>
<td>Up to 4% Improvement</td>
<td></td>
</tr>
</tbody>
</table>

Key Lessons Learned

• A strong team with complementary skills is a key asset:
  • Experts from academia, tier 1 supplier and world class testing facility enabled development and verification of technology tailored toward a production environment.

• Design a reliable baseline for “real-world” comparison of energy and mobility benefits:
  • OSU developed Enhanced Driver Model (EDM) to reconstruct response of human driver to variations in route, traffic and SPaT conditions, greatly improving repeatability of tests;
  • Adoption of Monte Carlo framework, comparing statistical distributions of energy consumption over large number of driving conditions.

• Target vehicle speed resulting from VD&PT optimization does not always match driver psychological expectations:
  • Minor sub-optimization of result is necessary for improved driver acceptability of technology.