RIDE QUALITY ASSESSMENT USING PROBE VEHICLE ACCELERATION MEASUREMENTS

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Probe Vehicle Concept

Fleet of on-road vehicles collect road data in real-time. Could include a fleet of instrumented vehicles or integrated production models used by normal drivers.
Probe Vehicle Potential Benefits

- Wider coverage on networks
- Low cost per unit of data
- Continuous and automated data collection
- No traffic disruptions
- Better representation of actual driver perception
Experiment

- Acceleration measurements taken from a Ford Fusion and a Volvo Truck.
- Profile data taken from a laser-profiler on the Virginia Smart Road.
- Acceleration and profile data repeatability
- Effect of test speed on vehicle vertical acceleration
- Effect of vehicle type on vehicle vertical acceleration
- Identification of rough spots
Evaluating Ride Quality

- Typically referred to as smoothness or roughness.
- Computed by measuring vertical deviations in surface.
- Measured by high speed laser profilers.
- Quantified using the International Roughness Index
Relation to Acceleration

- Road profile measures vertical variations in pavement.
- These variations are experienced by the vehicle.
- Vehicle accelerometers can document these changes.
- Bumpy areas of pavement display larger accelerations.
Virginia Smart Road

Virginia Smart Road

Road

VTTI

Bridge
Smoothness Comparison

[Graph showing smoothness comparison over distance in feet, with profile and acceleration metrics.]
Repeatability (Ford Fusion)
Cross-Correlation

- Used to verify the similarity of two waveforms.
- Amount of shifting that optimizes the cross-correlation is utilized to more accurately match waveforms.

\[
\varphi_{xy}(m) = E[x_n y_{n+m}] = \lim_{L \to \infty} \frac{1}{L} \sum_{n=0}^{L-1} x_n y_{n+m};
\]
Cross-Correlation

Maximum cross-correlation occurs at measurement 1047 (corresponding to a shift of 4 measurements)
## Acceleration Repeatability

<table>
<thead>
<tr>
<th>Measurement Type</th>
<th>Test Runs Compared</th>
<th>Value (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Deviation of Differences</td>
<td>Runs 1 and 3</td>
<td>0.0244</td>
</tr>
<tr>
<td>Standard Deviation of Differences</td>
<td>Runs 2 and 3</td>
<td>0.0206</td>
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<td>Standard Deviation of Differences</td>
<td>Runs 4 and 3</td>
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<td>Variance of Differences</td>
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<tr>
<td>Variance of Differences</td>
<td>Runs 4 and 3</td>
<td>0.00050327</td>
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</tbody>
</table>
Signal to Noise Ratio

- Std of Measurements divided by std of the difference between 2 measurements
- Ford Fusion: 1.73
- Profiler: 1.16
- Volvo Truck: 0.73
- Quality of measurement
Effect of Speed

Acceleration Measurements with Ford Fusion at Varying Speeds

Acceleration (g) - Zeried

Distance (ft)
Effect of Speed
Effect of Speed

10-90\textsuperscript{th} Percentile Ranges

- 40 MPH = 0.0551 g
- 50 MPH = 0.0783 g
- 65 MPH = 0.1340 g

Average Acceleration

- 40 MPH = 0.0258 g
- 50 MPH = 0.0296 g
- 65 MPH = 0.0474 g

- 14.7\% increase
- 60.1\% increase
Effect of Vehicle Type

![Graph showing comparison between Ford Fusion and Volvo Truck at 50 MPH](image-url)
Effect of Vehicle Type
Effect of Vehicle Type

- **10-90<sup>th</sup> Percentile Ranges (at 50 MPH)**
  - Ford Fusion = 0.0783 g
  - Volvo Truck = 0.1189 g

- **Average Acceleration (at 50 MPH)**
  - Ford Fusion = 0.0319 g
  - Volvo Truck = 0.0478 g
Acceleration Analysis

Maintenance strategies can tailor roughness thresholds to meet needs by section or spot location.
Conclusions

- Ride quality (smoothness) is a promising application of probe vehicles.
- Acceleration measurements exhibit an acceptable level of repeatability.
- Acceleration is sensitive to vehicle speed, type.
- Rough sections of pavement can be identified using threshold values.
Questions?