A MOBILE PROFILOMETER FOR ROAD SURFACE MONITORING BY USE OF ACCELEROMETERS

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Agenda

1. Motivation and Objective
2. Concepts of the New System
3. Configuration and Algorithm
4. Verification Experiment
5. Application Case Study
6. Conclusions
1. Motivation and Objective (1)

Evenness/Roughness

related to…
User’s safety and comfort, Vehicle operating costs, Road side environment, etc.

required to…
- Objective and high precision data collection
- High frequency monitoring
1. Motivation and Objective (2)

Current Surface Monitoring

- High-speed profilers (response- or profile-based)
- Visual inspections

problems are...

- too much cost for high-speed profilers
- calibration of response type systems
- the lack of accuracy by visual inspections
Objective of this Study

Development of a Mobile Profilometer

- using two small accelerometers
- collecting surface profiles and its roughness characteristics in real time
- making cost-effective, time-stable, and easily workable operation
2. Concepts of the New System (1)

Based on the Quarter-Car Model

- measuring surface profiles
- calculating the IRI

Golden Car Parameters
- $m_u/m_s = 0.15$
- $k_s/m_s = 63.3$
- $c_s/m_s = 6.0$
- $k_t/m_s = 653$
- $B = 250$ (mm)

Quarter-Car Model

The IRI Scale
2. Concepts of the New System (2)

Profiler Class – *how the measures related to the IRI*

- **Class 4** – can only be compared to IRI by subjective estimation (*ex.* Visual inspection)
- **Class 3** – calculating IRI by correlation with reference measures (*ex.* RTRRMS)
- **Class 2** – a profile-based method that is calibrated independently of other roughness measuring instruments (*ex.* Laser-profiler)
- **Class 1** – a profile-based method if it is so accurate that further improvements in accuracy would not be apparent (*ex.* Rod & Level)
2. Concepts of the New System (3)

Target of the System Development

Accuracy: Class 2, Convenience: Class 3

Classification of the Profiler and the Target of the New System
3. Configuration and Algorithm (1)

Using Two Small Accelerometers

Simply Operational (Class 3!!)
3. Configuration and Algorithm (2)

Can be Mounted in Any Vehicles

- Mechanically implements the quarter-car model
- Measuring surface profiles (Class 2!!)
- Independent of vehicle model and driving speed
3. Configuration and Algorithm (3)

Measurement Algorithm

- Measuring Acceleration (sprung & unsprung mass)
- Pre-processing: reduction of the velocity factors by digital filters
- Integration of Acceleration: calculation of velocities and displacements of the masses
- Response of the Digital Filter: simulation of the QC model
- IRI Calculation: computation of the IRI

Profile and IRI Measurement Algorithm
4. Validation Experiment (1)

Data Collection

- Survey Vehicle
- Mobile Profilometer
- Rod & Level Profilometer
- Reference Class 1 Measures
4. Validation Experiment (2)

Mobile Profilometer
- SUV Type (Road Patrol Car)
- 40, 60, and 80 km/h

Profile Measurement
- 200-m long asphalt pavement
- 0.1-m sampling interval
- 0.5 – 50-m wavelength (Unevenness)

Wavy Characteristics of Surface Profiles
4. Validation Experiment (3)

Comparison of Profile Measurements

Profile Measurement Result

Closely agree with the reference profile
4. Validation Experiment (4)

Comparison of Elevation PSD

PSD Plots of Profile Elevation

Same spatial characteristic of the profiles
4. Validation Experiment (5)

IRI Measurement by the Mobile Profilometer

✓ arbitrary intervals
✓ real time calculation and display

IRI for 200-m Interval

<table>
<thead>
<tr>
<th>The New Profilometer (Driving Speed)</th>
<th>Reference Profiler</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.80 (40km/h)</td>
<td></td>
</tr>
<tr>
<td>3.03 (60km/h)</td>
<td>2.78</td>
</tr>
<tr>
<td>2.72 (80km/h)</td>
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</tbody>
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(Unit: mm/m)

Within 10% accuracy
4. Validation Experiment (6)

**Continuous IRI**

✔ available for Localized Roughness Detection

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**IRI (10-m continuous)**

Finding the most severe parts of the profile

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**Graph**: IRI (mm/m) vs. Distance (m) for different speeds (40km/h, 60km/h, 80km/h). The graph shows peaks at specific distances indicating areas of higher roughness.
5. Application Case Study (1)

Roughness Data Collection:

- in the urban area of Kitami city, Hokkaido, Japan in November 2011 (3 days)
- on a national highway, prefectural roads, and city roads
- normal driving speed
- measuring IRI values of 100-m interval

Population: 124,000
Area: 1500km²
City Road: 1900km

Location of Kitami City
5. Application Case Study (2)

The selected levels of IRI categories were chosen for demonstration purpose.
5. Application Case Study (3)

Frequency Distribution of IRI

- National Highway
- Prefectural Road
- City Road

✓ will be improved after more data are collected
✓ contributes to prioritize budget
6. Conclusions (1)

Development of a Mobile Profilometer

✓ consists of two accelerometers
✓ measures surface profile
✓ calculates the IRI based of the profile measurements
✓ has good correlation with Class 1 profilers
✓ achieves the accuracy with 10% for the IRI
✓ enables localized roughness detection
6. Conclusions (2)

Case Study (IRI Mapping and Frequency Distribution)

- visually inspects pavement conditions using IRI mapping in the road network
- contributes to plan pavement maintenance and rehabilitation projects at the network level
- evaluates the current status of roughness levels against the whole of a road network
- prioritize budget allocation for pavement management projects
THANK YOU FOR YOUR KIND ATTENTION

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