On-board estimation of water depth using low-cost sensors

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Context

• Accident risks x2 on wet roads
• Wrong assessment of danger
  • Unsuitable behavior of the driver
• On-board friction estimation
  • On-board water depth measurement

SWOV, 2009
Methodology and Experimental Setup
Methodology

Vehicle

- High-cost Laboratory sensor
- Low-cost Industry sensor

Water depth

Indicator related to water depth

Correlation

Prediction model – vehicle implementation
Experimental Setup

**Laboratory Sensor**

- measuring range: 0 to 1 mm
- accuracy: 0.1 mm + WD/10
- response time: 0.01 s

Principle of spectroscopy
Experimental Setup

**Industrial Sensor**

- Sensibility: 1 mV by m²/s
- Bandwidth: 1 to 25000 Hz
- Max. peak acceleration: 7500 m²/s
Experimental Setup

Both measurements in the right running track

Industrial sensor

Laboratory sensor
Experimental Program
Experimental Program

**Tires**
- 2 manufacturers
- New / Worn
- Summer / Winter

**Speeds**
- 30, 50, 70, 90 and 110 km/h

**Pavements**
- 5 pavements (wide MPD range)
  → Ifsttar Test Track
Ifsttar Test Tracks

- 13 surface dressings
  - 100 to 250 meters long
- Wetting system
- Weather monitoring
## Tested pavements

<table>
<thead>
<tr>
<th>Type of pavement</th>
<th>Size of aggregates (min/max)</th>
<th>Acronym</th>
<th>Track Name</th>
<th>MPD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-coarse Asphalt Concrete (new)</td>
<td>0/10</td>
<td>SCAC 0/10</td>
<td>E1</td>
<td>0.66</td>
</tr>
<tr>
<td>Semi-coarse Asphalt Concrete (old)</td>
<td>0/10</td>
<td>SCAC 0/10</td>
<td>E2</td>
<td>0.82</td>
</tr>
<tr>
<td>High-friction chip seals</td>
<td>1.5/3</td>
<td>-</td>
<td>F1</td>
<td>1.17</td>
</tr>
<tr>
<td>Sand-Asphalt</td>
<td>0/4</td>
<td>-</td>
<td>L2</td>
<td>0.5</td>
</tr>
<tr>
<td>Very Thin Asphalt Concrete</td>
<td>0/10</td>
<td>VTAC 0/10</td>
<td>M1</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Mean Profile Depth (MPD) measured by the **Rugolaser** device

→ **macrotecture** measurement
Surface Wetting

Successive measurements when drying
Data processing and Results
Data processing

Signal processing + Filtering → Droplets speed indicator

Mean value along the track (≈250 m) → Measured water depth

accelerometric sensor system output [volts]

Measured water depth (Aquasens) [mm]
Results

**Droplets speed / Actual water depth**

Sand-asphalt (L2)

\[ V = 70 \text{ km/h} \]

Ind. = 0.11 \times \text{WD}_{\text{Aquasens}} - 0.01

\[ R^2 = 0.98 \]
Results

On-board prediction model development

Measurements → ANOVA → Interactions observations → Physical Model

Measurements → Supervised learning machine → Industrial prediction model
Developed Model
In prospect applications

- Detection of wet pavement
- Friction/aquaplaning models on-boarding
- Improvement of active-security systems
  - ABS
  - ESC
  - ACC
  - ...
- Road management

Real-time processing
Thank you

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