An Effective Pothole Identification and Measurement System Using Mobile Devices

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Potholes cost American drivers over $6 billion dollars per year. Potholes have become a leading cause of car accidents.
Typical cost to repair potholes is approximately $35 to $50 per pothole.

- Time-consuming
- Labor-intensive
- Costly
How to identify damaging potholes using mobile device?

New Pothole Detection Framework
Threshold + Wavelet Analysis
Data Collection
Potential Potholes Detection
Data Uploading

Mobile Sensors’ Data Collection

Web-based Data server

Raw Data
Potential Potholes

Potholes Verification
Size Measurement
Results Fusing
Reoriented smartphone’s axes align with vehicle’s axes \((ax=0, ay=0, az=-1 \text{ g m/s}^2)\)

\[
\alpha = \tan^{-1}\left(\frac{a_y'}{a_z'}\right) \quad \beta = \tan^{-1}\left(-\frac{a_x'}{\sqrt{(a_y')^2 + (a_z')^2}}\right)
\]

\[
a_{x\text{reor}} = c_\beta a_x' + s_\beta s_\alpha a_y' + c_\alpha s_\beta a_z';
\]

\[
a_{y\text{reor}} = c_\alpha a_y' - s_\alpha a_z';
\]

\[
a_{z\text{reor}} = -s_\beta a_x' + c_\beta s_\alpha a_y' + c_\alpha c_\beta a_z';
\]

In order to wipe off the noise from signals and smooth the raw data, a sliding window with a size of 0.5 m is required to be applied.

\[
\psi_{\text{rms}(x)} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} y^2_i(x)}
\]
--Large amplitude, short wavelength events in RMS curve
2 sensors:

- GPS Receiver & 3-axis Accelerometer

4 Functions:

- Log Data
- Analysis
- View Files
- Data Uploading
How to identify road-related leading factors of car crashes?

https://youtu.be/ervn5tVb_VU
2-phase Pothole Detection Framework

**Phase 1:** Mobile-based Threshold Analysis

**Phase 2:** Wavelet Analysis

Wavelet Analysis

File1: Potential Potholes

File2: Raw Data

0.253m 0.273m 0.124m 0.153m
Wavelet analysis characterizes the scale-dependent periodicity of a signal. It both reveals the frequency component of the signal and identifies where a certain frequency exists in the spectrum.

**Time series signal  ->  Spatial scale signal**

- Estimate pothole size
- Improve accuracy of detection
A **compressed** wavelet corresponds to a small size (high frequency)

\[ \psi(x) = (\pi b)^{-0.5} e^{2\pi i c x} e^{-\frac{x^2}{b}} \]

A **stretched** wavelet corresponds to a large size (lower frequency)
Continuous wavelet transform (CWT):

\[ CWT(a, \tau) = \int_{-\infty}^{\infty} f(x) \times \frac{1}{a} \psi^* \left( \frac{t-\tau}{a} \right) dt \]

Average Error: 9.615 cm

Wavelet coefficient image after thresholding

Threshold = 17 x average coefficient value
### Coverage Rate

<table>
<thead>
<tr>
<th></th>
<th>Positioning Accuracy 5 meters</th>
<th>Positioning Accuracy 10 meters</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>1 Time</td>
<td>5 Times</td>
</tr>
<tr>
<td>D_PEAK</td>
<td>12%</td>
<td>21%</td>
</tr>
<tr>
<td>D_DIFF</td>
<td>4%</td>
<td>12%</td>
</tr>
<tr>
<td>D_STEDV</td>
<td>9%</td>
<td>29%</td>
</tr>
<tr>
<td>D_IMPROOVED</td>
<td>25%</td>
<td>40%</td>
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</tbody>
</table>

### False Positive Rate

<table>
<thead>
<tr>
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<th>Positioning Accuracy 5 meters</th>
<th>Positioning Accuracy 10 meters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 Time</td>
<td>5 Times</td>
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<tr>
<td>D_PEAK</td>
<td>38%</td>
<td>30%</td>
</tr>
<tr>
<td>D_DIFF</td>
<td>50%</td>
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<tr>
<td>D_STEDV</td>
<td>48%</td>
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</tr>
<tr>
<td>D_IMPROOVED</td>
<td>38%</td>
<td>34.5%</td>
</tr>
</tbody>
</table>
Built-in smartphone sensors can be used to detect potholes.

Damaging potholes can be identify using **Threshold + Wavelet**.

By mining crowd sensed data, a more accurate and reliable result can be achieved.
Q & A
Thank You