Transverse Profile Measurement Accuracy

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Outline

Motivation for Accurate Surface Measurements
Transverse Profile Measurement Accuracy
  • Data Acquisition
  • Data Analysis
Conclusions
Motivation for Accurate Surface Measurements

Background on Existing Systems and Techniques

- Courtesy of James Tsai…
  - Existing Measurement Systems
  - Possible Sources of Error
  - Definitions of Calibration and Validation
  - Various Calibration Surfaces in Use
  - “It is suggested to use a standardized validation board to directly validate range measurement accuracy following a standard procedure”
    - Thank you, Yichang (James) Tsai!
Motivation for Accurate Surface Measurements

“Garbage in, garbage out”

- If we want to assess pavement surface distresses then we must begin with accurate pavement surface measurements

Not just, “Is the system acceptable”?  

- But also, “How accurate is this system?”
- Makes possible an informed, quantitative, cost/benefit analysis
Motivation for Accurate Surface Measurements

Need to know the sub-system accuracy

• Identify the area(s) where the errors are hiding
• Makes possible an informed, quantitative, *quality improvement plan*
• Calibrate our equipment and validate our processing and *improve our systems*

We are not alone…

• This is an issue for a many communities
Motivation for Accurate Surface Measurements

Sponsors

[Logos of sponsors such as NSF, Federal Highway Administration, NASA, Chrysler, Volkswagen, John Deere, INO, ATC, NAC, TARDEC]
Motivation for Accurate Surface Measurements

A loaded question, “How accurate is this system?”

Key elements to answer

• Is the test data useful?
  • What does data demonstrate about the system/components?

• Under what test condition(s)?
  • Each test is necessary, but not sufficient
  • More tests provide a more robust assessment

• How should the statement of accuracy be formulated?
  • Traceable to ground truth
  • Statistically sound, but understandable
Motivation for Accurate Surface Measurements

Quality Improvement in Data Acquisition

1993 – 2001
Chrysler

2001 - 2005
ZF Lemförder

2006 Vehicle Terrain Performance Lab

2008 TARDEC Profilometer

2011 Aberdeen Test Center Profilometer

vehicle. terrain. performance.
Motivation for Accurate Surface Measurements

Data Acquisition Examples from RPUG Demonstration

• Some examples (not all of the tests are presented here)
• Traceable to ground truth
• Test condition(s)
• Usefulness of the data
Data Acquisition

Ground Truth
• Flat beam

Test Conditions
• Static testing
• Various surface finishes

Usefulness
• Ability to establish a flat datum line, (from which rutting can be established) under various surface conditions
Data Acquisition

Ground Truth
- Flat beam
- Gauge blocks

Test Conditions
- Static testing
- Various surface finishes

Usefulness
- Ability to accurately measure changes in height at various lateral locations
Data Acquisition

Ground Truth
  • Calibration surface

Test Conditions
  • Driving test
  • No excitation

Usefulness
  • Ability to accurately measure surface when vehicle is not excited
Data Acquisition

Ground Truth
  • Station Marker

Test Conditions
  • Driving test
  • No excitation
  • Figure-8
  • Several minutes

Usefulness
  • Ability to accurately measure horizontal location without drift
Data Acquisition

Ground Truth
- Station Marker
- Calibration Plate

Test Conditions
- Driving test
- With excitation

Usefulness
- Ability to accurately measure surface while canceling vehicle body motion
Data Analysis

Terminology (Some of which seems inappropriate to me…)

Term: “Precise”
Statistic: standard deviation
(to me, this is ‘bad’, it clearly has errors)

Term: “Accurate”
Statistic: mean
(to me, this is also ‘bad’, it clearly has errors, perhaps ‘unbiased’ ?)

Define a measure that captures errors in both the mean and standard deviation

Consider the 90% confidence interval
Data Analysis

How best to quantify error or “accuracy”? Consider some height measurements.
No need to ‘bin’ the data
Data Analysis

So the 90% confidence interval for the height is
11.950 – 10.850 = 1.10 mm

What if the true height is 11.250 mm?
Then the 90% confidence for the error is
-0.4 mm to 0.7 mm
Data Analysis

A convenient way to represent this is a box plot.
Data Analysis

Entire set of *test results* and *specifications* could be written something like…

<table>
<thead>
<tr>
<th>Event</th>
<th>Lower Bound</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>50%</td>
<td>90%</td>
<td>50%</td>
</tr>
<tr>
<td>Confidence Used</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Straight Edge Test - For various heights from base measurement height</td>
<td>-25.4 mm</td>
<td>-12.7 mm</td>
<td>0 mm</td>
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<tr>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Guage Block Test - For various heights from base measurement height</td>
<td>-25.4 mm</td>
<td>-12.7 mm</td>
<td>0 mm</td>
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<tr>
<td></td>
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<tr>
<td>GPS Drift Test</td>
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<tr>
<td>Crack Detection Test</td>
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</tbody>
</table>

[Diagram showing box plots for different test results and specifications]
Conclusions

First steps toward

- Answering the question, “How accurate is this system?”
  - Traceable to ground truth
  - Statistically sound, but understandable
- Developing a process for informed, quantitative decisions
  - Cost/benefit analyses
  - Quality improvement plans

Questions?

Thank you!
Backup Slides
Vehicle Terrain Performance Laboratory (VTPL)

Terrain Surface Measurement

Data Collection

Base Station

- Differential GPS

In-Vehicle

- Relative position & orientation from laser to ground

Data Processing

- GPS/IMU Coupling

Absolute position & orientation vehicle & laser

XYZ Point Cloud Generation

- www.me.vt.edu / VTPL
Motivation for Accurate Surface Measurements

Terrain Measurement → Terrain Modeling

Analysis and Prediction
- Virtual Proving Grounds
- Driver Assistance Systems
- Automated Vehicles

Vehicle Modeling
Sample of Relevant Journal Publications


Sample of Relevant Journal Publications


Sample of Relevant Journal Publications


Sample of Relevant Conference Publications


Sample of Relevant Conference Publications


Sample of Relevant Conference Publications


*current or former student

** current or former intern