FUSION OF LIDAR AND PROFILE FOR PAVEMENT CONDITION ASSESSMENT

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LIDAR

- Light Detection and Ranging
- Laser technology capable of imaging a huge range of material types
- Precision range-finding using “time of flight” analysis
- Multi-directional scanning using spinning lasers
- To provide a 3D dataset of the surveyed asset

This presentation: could we add LIDAR to our kit of asset and pavement assessment tools?
Collecting LIDAR data

- “Traditional” surveys are airborne e.g.
  - Helicopter surveys @100-400m altitude
  - Surveying 60m “strips”
  - 50km/day
  - Claiming @5cm accuracy
- LIDAR, inertial and GPS data are combined
  - May use a local GPS base station
- Terrestrial surveys also undertaken using specialist vehicles
Common applications

• Pavement, roadside infrastructure, built and natural environments all mapped simultaneously
• For design and planning
  • Accurate 3D maps feed CAD design tools
• Assessing Earthworks
  • Slope instability
• Asset inventory
LIDAR surveys

- Airborne surveys are very useful, but
  - Specialist / expensive
  - Complex
  - Coverage issues - can’t measure underneath the assets
- In general
  - Focused on in-depth scheme/project level assessment (high value)
  - Accuracy may not be suitable for pavement surface/shape assessment, even for terrestrial surveys
Profile surveys

- Routine laser profile surveys measure
  - Transverse profile
    - Rutting
    - Water depth
  - Longitudinal profile
    - Ride quality (IRI)
  - Texture profile
    - High-speed skid resistance
  - Geometry
- Very accurate profile data
- Limited to a single lane per survey
- High efficiency (300km / day)
- Low cost
Terrestrial LIDAR (vehicle based)

- Collection by installing Velodyne LIDAR head on a Profile survey vehicle (HARRIS2)
- LIDAR system gives distance from the laser only
- Onboard GPS and IMU needed to relate LiDAR data to the surrounding environment
  - Conversion from the LIDAR space to the Survey space
LIDAR Space

- The Velodyne LIDAR provides a head rotation angle and 32 distances (one per laser in each bank)
- Azimuthal and rotational angles of the individual lasers are provided in a separate file
- The location of each observed point is determined w.r.t the base of the LIDAR unit
Vehicle space

- LIDAR head is mounted at a 23 degree angle
- Position and orientation of LIDAR head used to rotate the LIDAR space position into Vehicle space
- The (0, 0, 0) point is at the location of the inertial measurement unit
- Vehicle space is ‘at rest’ w.r.t vehicle
- Pitch, Roll and Yaw are not considered yet
Survey Space

- IMU provides Pitch, Roll, Yaw (Bearing), Location and Altitude
- \((X, Y, Z)\) in vehicle space is rotated and translated to locate the point in survey space \((E, N, Alt)\)
- Software tool developed to carry out these transformations
- Resulting data set is a 3D point cloud \((x, y, z, r, g, b)\)
Results

- LIDAR space
- Same data in Survey space
Results
Applications - measuring assets

- Easier to collect routinely, with potential to (e.g.)
  - Locate signs and signals.
  - Generate a geo-referenced database of signals and signs
  - Locate and measure bridges, gantries etc
  - Enhance right of way video data for quantitative assessment
Applications - pavement condition assessment

- E.g. Potential to
  - Automatically identify the edges of the road.
    - Measuring road width and
    - Identify narrow locations automatically
  - Measure overall shape
    - But still may not be suitable for condition assessment
How accurate is it (ideal conditions)?

• Performance linked to quality of:
  • LIDAR head
  • IMU
  • Algorithms
  • Vehicle mounting
  • IMU / LIDAR coupling hardware

• In static conditions:
  • Overall we observe cm accuracy
  • Therefore still restricted in application for pavement condition assessment?

<table>
<thead>
<tr>
<th>Sphere</th>
<th>Riegli LIDAR measured (cm)</th>
<th>True Dimensions (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius</td>
<td>X</td>
<td>Y</td>
</tr>
<tr>
<td>A (20cm)</td>
<td>20</td>
<td>548</td>
</tr>
<tr>
<td>B (20cm)</td>
<td>20.2</td>
<td>549</td>
</tr>
<tr>
<td>C (10cm)</td>
<td>11.2</td>
<td>488</td>
</tr>
<tr>
<td>D (10cm)</td>
<td>11.7</td>
<td>464</td>
</tr>
<tr>
<td>E (10cm)</td>
<td>N/A[2]</td>
<td>N/A^5</td>
</tr>
<tr>
<td>F (10cm)</td>
<td>12.7</td>
<td>120</td>
</tr>
<tr>
<td>G (10cm)</td>
<td>11.9</td>
<td>140</td>
</tr>
<tr>
<td>H (20cm)</td>
<td>21.1</td>
<td>30</td>
</tr>
</tbody>
</table>
How accurate is it (real application)?

- Assessment of bridge / gantry clearance
- Using the LIDAR Slice approach
How accurate is it in a real application?

<table>
<thead>
<tr>
<th></th>
<th>Closest Point</th>
<th>5&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>10&lt;sup&gt;th&lt;/sup&gt; Percentile</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>5.152</td>
<td>5.156</td>
<td>5.159</td>
<td>5.05 (nearside) to 5.16 (offside)</td>
</tr>
<tr>
<td>Width</td>
<td>15.161</td>
<td>15.215</td>
<td>15.267</td>
<td>15.7 (at the road barrier) to 15 (at the bridge deck)</td>
</tr>
</tbody>
</table>

- Example on a sample bridge
- LIDAR results obtained using an algorithm to radially assess each slice
- Reference data using a laser distance tool on site
- Reasonable results – few cm accuracy
An example “routine” application

- Manual assessment of barrier height and offset
- Using the LIDAR Slice approach
- 200km of M25 surveyed in 1 day
- Manually determine heights and offsets
  - Using software tool
  - A few day’s analysis
An example “routine” application

- Automatic assessment of barrier height
- Using the LIDAR Slice approach
- Developed algorithms to estimate the height of the road and the barrier in each slice
- Processing takes a few minutes
- Compare with manual assessment of the LIDAR data
- >75% within 10cm
Can it be used for pavements?

- Profilers survey the lane
  - 20-1000 points across the lane
  - To 1/10th mm accuracy
  - Every 5-100mm along the road
- Can only assess in-lane condition
- Desirable to survey the whole carriageway to this level
  - Handling models
  - Water depth
  - Splash/spray
Fusion of LIDAR and profile

- Report the LIDAR and the profile data in the survey space
- A survey is made in each lane using the profiler and LIDAR
  - Cannot simply add together the profile data due to drift and inaccuracy
- A single lidar run selected to provide the baseline
- Each run of profile is “overlaid” onto this
- The profile is shifted to align using reference points identified in the LIDAR
Fusion of LIDAR and profile

• We get a single 3D dataset with
  • cm accuracy for the surrounding assets
  • mm accuracy for the pavement

• But we still have some problems!
  • Stepping still present
  • Need for manual intervention
Summary

- LIDAR is an established technology, used for planning and design
  - Often using airborne surveys
  - Little used in pavement assessment
- With developments in LIDAR, inertial GPS and cost reductions, it is a viable technique for installation on survey vehicles
  - With some advantages over airborne surveys
- Requires suitable equipment and algorithms to create the 3D data
- On its “own” it cannot yet replace high resolution profilers for pavement assessment
- But has some valuable potential in measuring assets adjacent to the pavement
- A multi-purpose vehicle combining LIDAR and profile could allow merging of the data to generate a full carriageway 3D profiler
- Further development of the approach is ongoing