Optical non-contact railway track measurement with static terrestrial laser scanning

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Example of Monitoring Requirement
4.6 Twist

4.6.1 Definition

The algebraic difference between two cross levels taken at a defined distance apart, usually expressed as a gradient between the two points of measurement.


Traditional track monitoring

Intrusive

Occlusions

Expensive

Maintenance

Discrete

Possessions and permits
Traditional track monitoring

- Intrusive
- Occlusions
- Expensive
- Maintenance
- Discrete
- Possessions and permits

Traditional track monitoring

- Intrusive
- Occlusions
- Expensive
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- Discrete
- Possessions and permits
Previous Work: Meng et al (2014)

- Extracting track from static TLS data of lab track
- Edge detection algorithm (vertex normal approximation) to produce trajectory line from 3D mesh
- Accuracy of trajectory line compared to ground truth
  - 2mm in Vertical
  - 3mm Horizontal

Accuracy determination of extracted track with ground truth points.
Image taken from Meng et al (2014)

- Uncertainty if model conforms to physical form of track
Previous Work:
Liu et al (2013)

- Static TLS to extract track geometry for deformation of high-speed rail
- 1mm cross-sections track extracted
- Classification using curves and lines
- Gauge and cant accuracy better than 3mm compared to precise levelling/track inspection car
- Accuracy affected by sampling interval + laser/track interaction

Previous Work:
Soni et al (2014)

- Extraction and Classification method for measuring track geometry
- Registering different sections of track profile (head, web and foot) to design rail model
- Better than 3mm RMS registration for Time-of-Flight and Phase Based Scanners

Summary of RMS values of fitting point cloud to modelled track.
Case Study: London Bridge Station

Prism Monitoring

Key:
- Target
TLS Data Capture

Data Capture
Profile of Track from TLS

SCAN A (from platform level)

SCAN A (from platform level)

SCAN B

Output Sections

Typical 500mm section extracted in Cyclone
Data Cleaning

Plane fit RMS = 2.6mm

Plane fit RMS = 0.6mm

Reference Lab Track

Plane fit RMS = 0.6mm
Rail Fitting

Point cloud planar areas ➔ Design rail model

CloudCompare v 2.5.5.2

Rail Fitting Results

Scan C ➔ Scan A
Scan D ➔ 24m ➔ 9m ➔ 6m ➔ 3m ➔ 0m ➔ Scan B
## Rail Fitting Results

### Rail Fitting from Scan A&B

<table>
<thead>
<tr>
<th>Track</th>
<th>Local plane fit RMS (mm)</th>
<th>Combined plane fit to rail RMS (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PL1</td>
<td>PL2</td>
</tr>
<tr>
<td>Track 1</td>
<td>1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Track 2</td>
<td>0.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Track 3</td>
<td>0.7</td>
<td>1.3</td>
</tr>
<tr>
<td>Track 4</td>
<td>1.1</td>
<td>1.3</td>
</tr>
</tbody>
</table>

### Rail Fitting Results

- **Scan A**: 0m, 2.5m, 5m, 7.5m, 10m, 15m
- **Scan B**: 0m, 2.5m, 5m, 7.5m, 10m, 15m
- **Scan C**: 0m, 2.5m, 5m, 7.5m, 10m, 15m
- **Scan D**: 0m, 2.5m, 5m, 7.5m, 10m, 15m

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FIG Working Week 2015
### Rail Fitting Results

#### Rail Fitting from Scan C&D

<table>
<thead>
<tr>
<th></th>
<th>PL1</th>
<th>PL2</th>
<th>PL3</th>
<th>PR1</th>
<th>PR2</th>
<th>PR3</th>
<th>Combined plane fit to rail RMS (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track 1</td>
<td>1.0</td>
<td>1.1</td>
<td>1.2</td>
<td></td>
<td></td>
<td>1.3</td>
<td>PR1,PR2,PR3 or PL1,PL2,PL3 (i.e. left or ride side of track)</td>
</tr>
<tr>
<td>Track 2</td>
<td>0.8</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Track 3</td>
<td>0.7</td>
<td>1.1</td>
<td>0.8</td>
<td></td>
<td></td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Track 4</td>
<td>1.1</td>
<td>1.5</td>
<td>1.2</td>
<td></td>
<td></td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

### Track Geometry for Engineers

<table>
<thead>
<tr>
<th>Monitoring method</th>
<th>Cant values (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring Contractor (prisms)</td>
<td>5.3</td>
</tr>
<tr>
<td>Rail Fitting method</td>
<td>5.1</td>
</tr>
</tbody>
</table>
Conclusions

• Complexity of the physical and logistical environment for data capture
• Improved quality of rail fitting a point cloud of track to UK standard design model to **1.5mm**
• Scans of track from 9m & 15m range produce comparable results (local and combined registration processes)
• Narrows gap between engineering requirements for deformation monitoring + TLS capabilities
• Local plane fitting and analysis of histograms provide mechanism for removal of track artefacts
• Automation of the method is possible through local plane fitting and analysis of histograms provide mechanism for removal of track artefacts
• Ongoing work - performance of geometry calcs for engineers

Further Work

• Investigation of the systematic bias in the spread of the residuals
  • Physical interaction of TLS + track
  • Develop robust statistical testing procedures for artefact removal
• Application to mobile rail mounted system for asset management