Use of Laser Triangulation and Deep Neural Networks (DNNs) for Railway Track Safety Inspections

Project Introduction and Update

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Industry Partners Meeting
16 October 2019
Tucson, AZ
Outline

► Background and approach
  • Project overview
  • Current inspection characteristics
  • Potential inspection improvements

► Technology and methodology
  • Railmetrics prior experience
  • Deep neural networks
  • Data collection methods

► Progress to date
  • Features of interest
  • Areas inspected
  • Current results
  • Challenges

► Path forward
Project Overview

► **Mission** – Evaluate the potential for use of Laser Triangulation and Deep Neural Network (DNN) technologies to provide value-added inspection data to existing geometry car inspection systems

► **Objectives:**
  - Improve railway network safety through improved reliability and robustness of track inspections
  - Provide value-added inspection data to existing geometry car inspection systems in operating conditions that include both:
    - Locations without a priori knowledge (e.g., the first inspection of a given route)
    - A posteriori scenarios (e.g., a repeat inspection of a route)

► **Timeline:** May 2019 → August 2020
Project Approach

► Use Railmetrics sensors to **collect data on the High Tonnage Loop (HTL)** at the Transportation Technology Center (TTC).
  - Tonnage accumulated by Facility for Accelerated Service Testing (FAST) train operations.

► Scans will be analyzed by RailTEC @ Illinois researchers in order to identify locations with defects and/or degradation in order to **build a condition database**.

► This database will be used by Railmetrics to subsequently **train a DeepCNet-based neural network** in the automated identification of features of interest.

► **Evaluate performance of the DNN** through the analysis of a separate set of test data and comparison of the DNN’s outputs to experts.
  - Goal of at least 75% agreement between the DNN and expert raters
Current Methods and Proposed Technology

► Current visual inspections (FRA Class 6+)
  • Costly
  • Time consuming
  • Risk associated with personnel on track
  • Impact track capacity

► Alternative technologies
  • Machine learning (in use in industry)
    - Process large amounts of data
    - Reliant on human recommendations
    - Limited to problems designer can solve
  • Deep Neural Network (DNN)
    - Subset of machine learning
    - Develop own analysis method
    - No retraining
Railmetrics Data Collection

Successive Scans are Compiled to Form a Continuous Image

Road/Runway/Tunnel/Rail Surface

Content Developed in Part by Railmetrics
Successive Scans are Compiled to Form a Continuous Image
Successive Scans are Compiled to Form a Continuous Image

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Railmetrics Data Collection

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Scanning Technology

► Two types of scans combined for analysis
  • Unique to Railmetrics

► Intensity Scan
  • Measure intensity of laser light reflected off surface
  • Produce black and white image

► 3D Scan (“Range”)
  • Measure elevation
  • Produce 3D profile
3D Scan ("Range")

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Combined Result

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Benefits of Two Scans

This is an “Intensity Image” Can you tell which ties/sleepers are bad just by looking at them?

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Benefits of Two Scans

This is a “Range Image”; we can now detect a bad tie that appeared to be cracked, but isn’t.

This tie appeared to be cracked, but isn’t.

This is a “Range Image”; we can now detect a bad tie that appeared to be OK based on the Intensity Image alone.

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High-Rail and Trailer

► Optical wheel encoder
  • Back of trailer
  • Rolls on wheel
  • Trigger image capture

► Data capture
  • RailTEC and/or Railmetrics personnel on site at TTC
  • Images relayed from trailer to computer in high-rail vehicle
  • Uploaded to Railmetrics database for further processing and transfer to RailTEC
Project Breakdown Overview

► Phase 1:
  • Task 1 – Project initiation
  • Task 2 – Definition of safety parameters for analysis
  • Task 3 – Sensor installation and field data collection
    - Ground truth inspection
    - High rail inspection

► Phase 2:
  • Task 4 – Development of features-of-interest database
  • Task 5 – DNN training

► Phase 3:
  • Task 6 – DNN testing and evaluation
  • Task 7 – Final reporting and results dissemination
Ground Truth Walking Inspections

► Record of features of interest
  • Spreadsheet list of features prepared prior to arrival
  • Use tablet to categorize ties by type, section and number
    - Concrete, timber, composite, etc.
  • Subcategories for features
    - Missing spike, center crack, broken clip, etc.

<table>
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<tr>
<th>Tie #s</th>
<th>Cent. Crack</th>
<th>Long. Crack</th>
<th>RSD</th>
<th>Broken Shoulder</th>
<th>Insulator Defect</th>
<th>Missing Dowel</th>
<th>Broken Dowel</th>
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Summary of Progress to Date

➤ Ground Truth Inspections
  • Documented fifteen different features of interest
    - Multiple of same defect documented once per tie
  • Approximately 7,500 ties inspected

➤ Data Collection via High-Rail
  • 5 weeks of data collection
  • Average 3 runs per week

➤ Challenges
  • Inconsistent judgement
    - Raised spike
  • Major issues repaired before detection
    - Broken tie plates
    - Clusters
  • Intentional variance interferes
    - Different manufacturers for similar tie plates
Ground Truth Summary

Approximate number of ties inspected: 7,500
Path Forward

► Weekly data capture on HTL
  • During Fall 2019 FAST operations
  • Walking inspections as needed

► Initial processing of data for automatic identification of features (Railmetrics)

► Tag new “features of interest” (RailTEC)

► Train DNN (Railmetrics)

► Evaluate DNN performance (Railmetrics)
Acknowledgements

► Research Sponsor:

[Image of U.S. Department of Transportation Federal Railroad Administration logo]

► Subcontractor:

[Image of Railmetrics logo]

► Industry Partners:

[Image of BNSF and CN Railway logos]

► Field Testing Support:

[Image of ICCI logo]
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