RAIL HIGHWAY GRADE CROSSING
ROUGHNESS QUANTITATIVE
MEASUREMENT USING 3D
TECHNOLOGY

Teng (Alex) Wang, Reginald
Souleyrette & Jerry Rose
University of Kentucky
Lexington, KY
Introduction

Background:

- highway-rail grade crossing is unique
  - Weak link (suboptimal design)
  - High growth in rail and truck traffic predicted
    - Congestion/delay
    - Tonnage, VMT and damage
    - In general ... conflict
  - Over 216,000 rail highway grade crossings in the US and over 9000 in the state of Kentucky alone (FRA)
Concerns

Safety ...

- 1,963 rail highway crossing incidents in 2012 and over 1,300 incidents in the first eight months of 2013 (FRA)
- High-centered crossing collisions between train and truck (hump)
- Crossing roughness related to highway safety
- Safety models (e.g., WBAPS) do not include hump or roughness
Concerns

Infrastructure (system preservation) ...
- Asset management
  - Preventive maintenance
  - Vehicle damage
  - Public (customer) service (rideability)
- Conventional inventory method
- No quantitative method currently exists
- Evaluate the physical performance of crossings
  - Design, materials, construction and environment
  - Conventional measurement methods
  - Limitations
Objectives

• Capture terrain economically and quickly
  • For ride/hump
  • For design/materials performance

• Quantify roughness
  • Measured accelerations (accelerometer)
  • Estimated accelerations (terrain model + dynamic model)

• Develop measures for systematic assessment
Meanwhile ... technology advances

- Developments in computer science
- 3D sensing and imaging technologies
  - LiDAR
  - Photogrammetry
  - Kinect sensor
  - Structured light
3D Structured Light

A low-cost 3D imaging technology (structured light 3D scanning) uses projected light patterns and a high resolution digital camera system to measure the shape, depth and surface information of an object.
Design and Build Data Acquisition System (DAS)

- Minimum scan area of 3’x5.1’ @ 42” above ground.
- Maximum scan area of 6’x10.2’ @ 80” above ground.
- DAS camera has 1280*800 pixel resolution.
- Pixels are about 0.25 centimeters average in size @ 80” above ground.
- Scan at a rate of about one scan per 30 seconds in the field.
- $5,000.
Design and Build Data Acquisition System (DAS)

- Two 3D structured light scanners.
- A rail cart was built to include a frame with wheels.
- A laptop computer with structured light data capturing software.
- An 1100 watt AC/DC converter.
- Power cables.
- Power provided by the battery of a test vehicle

DAS prototype
Several field tests have been conducted at crossings around Lexington, KY and at the site of the Bluegrass Railroad Museum in Versailles, KY.

At crossing (USDOT 719862A) on Beasley Rd. Versailles, KY.

- total 52 scans collected
- 2 hours
- 6’x10.2’ in size
- one foot overlapped area in the longitudinal direction
Data Analysis

• Each 3D point cloud “tile” is measured as 10’ x 6’ in area.
• 1280 x 800 resolutions.
• File size is about 30 Megabytes.
• Every two adjacent scans can be stitched and merged by using data comparison within the overlapped area.
A highway rail crossing surface 3D points cloud
After the all 3D points cloud tiles were merged into one crossing surface, each point had X, Y, Z coordinates recorded (to the nearest millimeter).

A color coded rendering of the crossing surface elevation is shown here. **Blue** indicates lower elevation, while **Red** shows the higher elevations.
Using the 3D point cloud, crossing roughness may be quantified as depth and area of cracks, area and volume of bumps or pot-holes, or other formulations. An example displaying surface curvature gradient is illustrated below. Blue areas are relatively flat as compared to Red areas in this visualization.
Long-Term Trackbed Settlement on Approaches and through Crossing

(20 Crossings in Study)
Representative Data for one Rail/Highway Crossing. Average Settlements through Crossings was 42% of Settlements on Approaches for the 20 Crossings.
Accelerations

Field Data Collection:
• Acceleration Collection Using accelerometer
Field Data Collection Result

Carbody Z Acceleration - 25 mph

Z Acceleration (m/s²)

Time (sec)
Wheel Path Crossfire Radar
Vehicle Dynamic Model

Vehicle Dynamic Model Simulation:
Vehicle Wheel Path

Path A - Z vs. Y Position

Path B - Z vs. Y Position
Vehicle Dynamic Model Simulation
Simulation Result

Carbody Z Acceleration - 25mph

Z Acceleration (m/s²)

Time (sec)
Next Steps

1) Validation of the accuracy of the resulting point clouds using established precision measurement (e.g., LiDAR, total station surveying) for:
   a. Roughness and vehicle accelerations
   b. Materials performance

2) Development of a roughness index based on crossing geometry

3) Development of a crossing condition index based on vehicular accelerations for a design vehicle(s).
Acknowledgements
Questions?

Thank you!