BBD 2019 Lightning Talks

Akintunde

Alhowaidi

Brillouin Fiber-Optic Distributed Sensing: Instrumentation Strategy for Bridge Monitoring

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Introduction

Distributed strain and temperature measurements :
Strain and temperature measurements using distributed fiber-optic strain sensors (FOS) are being widely used nowadays for structural monitoring. Two main advantages are :

- They provide continuous measurements; compared to the discrete measurements at a certain location by using conventional strain gauges or Fiber Bragg Grating (FBG) cables.
- They provide a tremendous number of measurements from a single cable. Strain at every 10 cm for a length of up to 100 km can be monitored.

From a geotechnical point of view, FOS also enables:

- Direct burial in the soil for settlement prediction
- Cavity formation detection by placing the fiber optics in the backfill under the approach
- Monitoring of slope stability
- Etc.

Objectives

Identify a good approach to enhance the use of fiber optics sensing techniques in terms of choice of an adequate cable and installation techniques in the geotechnical field.

Fiber optics cable and Analyzer

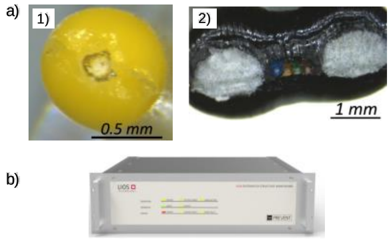


Fig 1: a) cross sections of the cable used in this study:1) Unjacketed cable. 2) Jacketed cable with extra fibers to add redundancy and b) BOTDR analyzer used in this study

BOTDR Working Principal

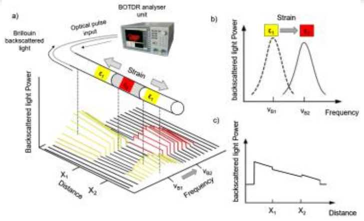


Fig 2: Illustrative diagram showing the concept behind Brillouin Optical Time Domain Reflecometry

Testing setup and methodology

- In the first test setup, the jacketed fiber optics cable was stretched and anchored with PVC pipe from both sides before being epoxied to the surface of a steel cantilever beam shown in Figure 3.
- The beam was loaded gradually in four stages, and the measured strain values is recorded from the strain gauges and the FO all together.

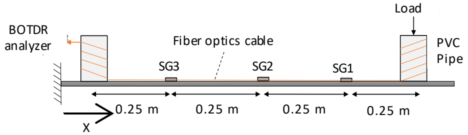


Fig 3: Illustrative figure of first test setup

- In the second setup, a composite beam was tested.
- The jacketed fiber cable was stretched around anchors as shown in Figure 4.1 ,
- A PVC pipe was inserted under the beam as shown in Fig 4.2 inducing strains which were monitored by the fiber optics cable and the strain gauges attached to the beam simultaneously.

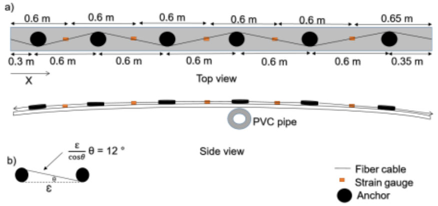


Fig 4: Illustrative figure of second test setup

- In the third setup, the composite beam was grooved, and the unjacketed fiber optics cable was inserted and epoxied within as shown in Figure 5.
- Like the previous test, a PVC pipe was inserted, and the resulted strain was measured from the strain gauges and the fiber optics at the same time.

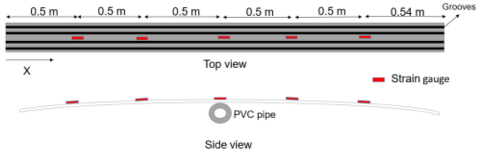


Fig 5: Illustrative figure of third test setup

Results

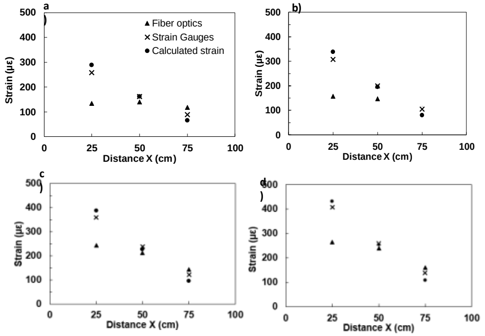


Fig 6: : Comparison between the calculated and measured strain values from fiber optics and strain gauges from the first test setup shown in Figure 3; (a) : first loading stage , (b) second loading stage, (c) third loading stage and (d) is the fourth loading stage

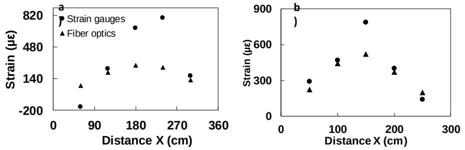


Fig 7: Comparison between the resulted strain from the conventional strain gauges and fiber optics from testing of the composite beam; a) second test setup shown in Figure 4 and b) The third test setup shown in Figure 5

Discussion

- In the first test, the trend of the results are similar between the calculated and the measured values from the FO and strain gauges especially at 50 cm and 75 cm away from the fixation point. Anyhow, the difference in the strain values between FO and SG enlarged near the fixation point which could be related to a possible internal slippage of the fiber cable at that location.
- In the second test, the same jacketed cable used in the first test is used here, the resulted strain from the FO at some location were close to that measured from the SG. Nevertheless, the maximum values observed at the middle of the beam from SG differed enormously from the measured values from FO. These differences might be related to internal slippage in the jacketed fiber cable.
- In the third test, an unjacketed cable was stretched and epoxied within the groove. The trend of the resulted strain is matching. However, at the point of maximum strain in the middle, the strain value from the SG differed from the corresponding FO strain. This could be related to possible slippage of the fiber in the used epoxy.

Future work

- Monitoring of approach slap settlement and cavity prediction. By installing fiber optics cable under the approach slab, a continuous strain map will be obtained, and will provide an insight to any possible cavity formation beneath the slab.
- Monitoring of the strains in abutment piles by attaching the fiber optics cable along the piles itself.

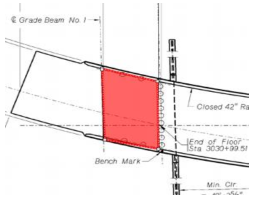


Fig 8: Approach slab instrumentation plan

Acknowledgment

We thank Nebraska Department of Transportation (NDOT) for there support and funding on this project "M087 - Design Optimization and Monitoring of Joint-less Integral and Semi-Integral Abutment Bridges in Nebraska."

Alhowaidi

Catch Intelligence

Full-Scale Experiments for Development and Validation of a Robust Damage Detection Tool

Emmanuel Akintunde[1], Saeed Eftekhar Azam[2], Ahmed Rageh[1], Daniel Linzell[3]
[1]Graduate Research Assistant, Research Assistant Professor, [3]Professor; Department of Civil Engineering, University of Nebraska-Lincoln

Background and Objective

- The Aging Infrastructure, climate change, and increased traffic load and frequency motivate monitoring the infrastructure health.
- In the context of transportation infrastructure, visual inspection is not sufficient and could be inefficient.
- This necessitated extensive research on smart monitoring of structural condition.

Fig 1: Florida International University Bridge collapse

Scope

- Finding damage features that are independent of traffic load intensity and speed and are robust to measurement noise.

Test Overview

Vehicle/Load Specifications
- Dump Truck (Empty and Filled)
- Small Truck (5, 10 & 15mph)

Bridge State Specifications
- Healthy Bridge (D#0)
- Crash-Induced Damage (D#1)
- Guard Rail Damage (D#2)
- Slab Deck Damage (D#3)

Fig 2: Dump Truck (Filled)

Fig 3: Small Truck

Fig 4:The Test Bridge

Instrumentation Plan

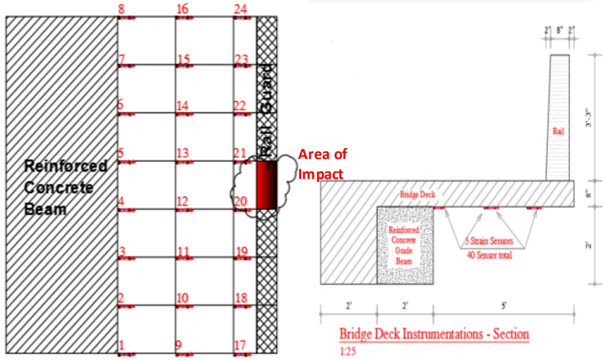


Fig 5: Plan and Section of the Bridge deck Instrumentation

Evolution of POMs in Time

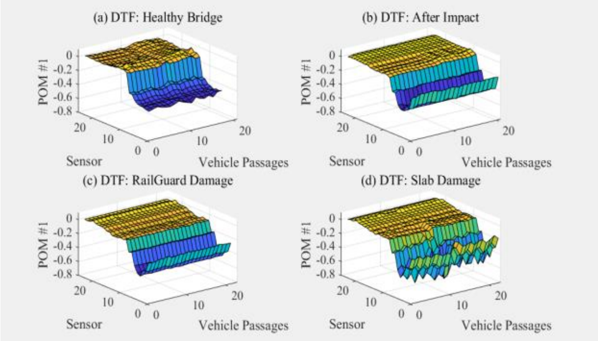


Fig 6: POMs for Filled Dump Truck

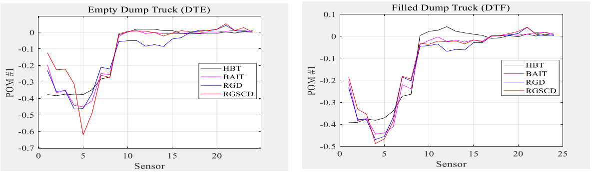


Fig 7: Mean POMs for Empty and Filled Dump Truck respectively

Unsupervised Damage Detection

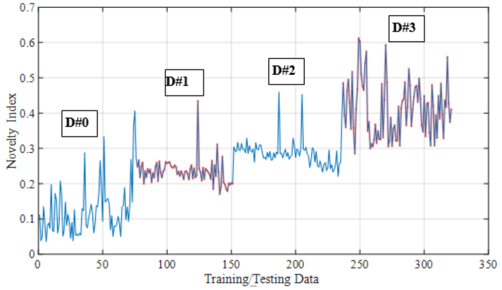


Fig 8: Novelty Detection from the POMs using Sensors 1- 24

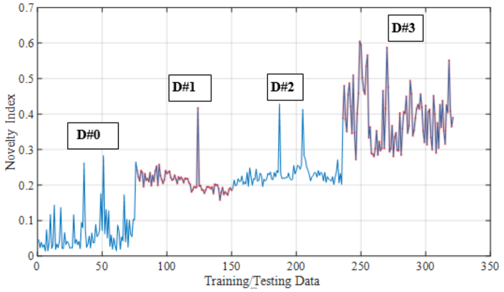


Fig 9: Novelty Detection from the POMs using Sensors 1-8

Conclusions, Future Work

- The damage feature (POMS) can effectively identify damage with even relatively low intensities.
- Strain based POMs provide robust damage detection methodology.
- Unsupervised Learning – In progress

References

- :Eftekhar Azam S, Rageh A, Linzell D. "Damage detection in structural systems utilizing artificial neural networks and proper orthogonal decomposition

Catch Intelligence

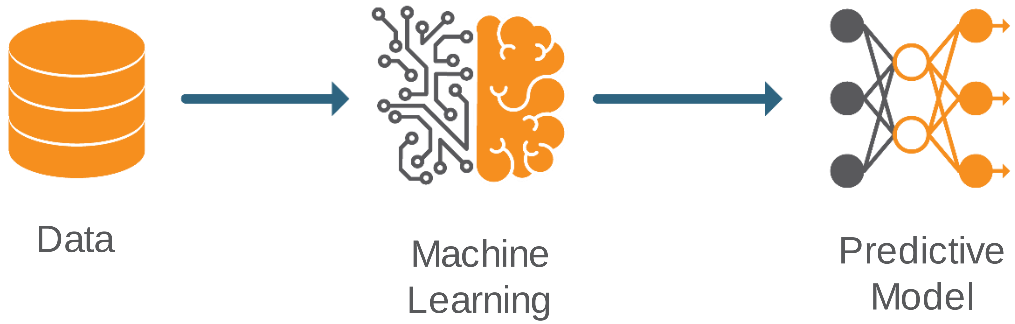
Chin

According to ARTBA (2019) there are 235,020 bridges - **38% of the bridges across the United States** - in need of structural repair, rehabilitation, or replacement.

The estimated cost to make the identified repairs is nearly **$171 billion**

American Road & Transportation Builders Association 2019 Bridge Report

CATCH Intelligence recommends utilizing **Predictive Analytics** **to optimize project prioritization and bridge repair costs**



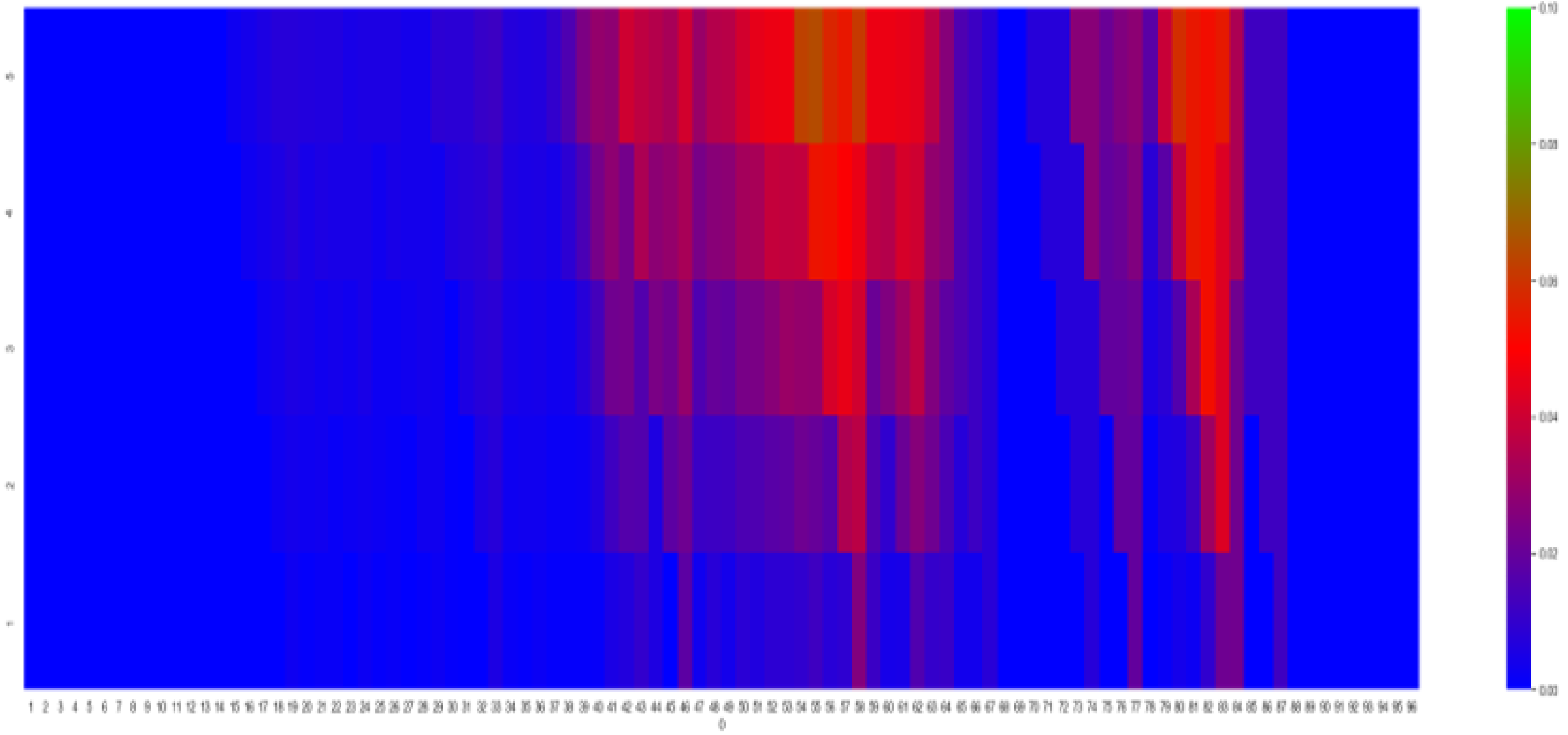
Benefits of Predictive Analytics

- Accurately forecast maintenance and reconstruction plans
- Accurately identify roads and bridges for repair
- Boost confidence in project cost estimation
- Plan for most effective letting dates

Chin

Eftekhar

Nebraska Bridge Age x Maintenance



Eftekhar

Kale

Virtual Sensing and Machine Learning for Low-Cost Bridge Health Monitoring

Saeed Eftekhar Azam (Ph.D.), Ahmed Rageh (Ph.D. Student), Daniel Linzell (Ph.D., P.E., F. ASCE)
University of Nebraska-Lincoln

Bridge Problems

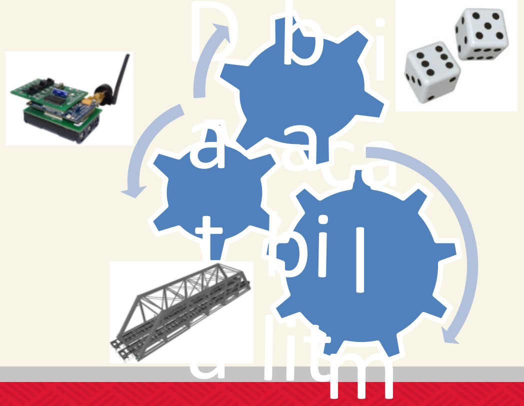
- Economic loss
- Lives loss
- Environmental impacts

Bridge Load and Speed Posting

- Traffic slowdown
- Transit detour – delayed goods delivery

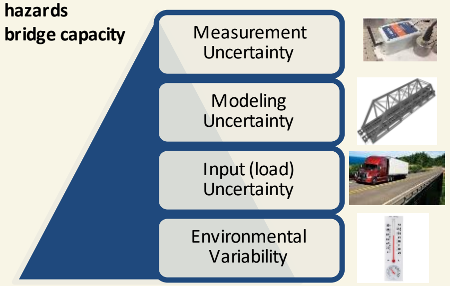
Solution: Big Data Analysis and IoT

- Big Data measured from bridges
- Machine Learning applied to sensor data
- Computational Modeling for mimicking bridge behavior



Challenges: Uncertainty

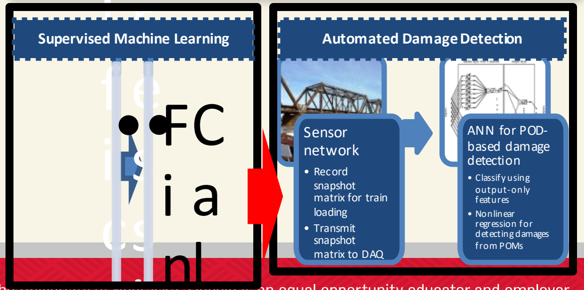
- Decision-making under uncertainty
- Uncertain loads
- Uncertain hazards
- Uncertain bridge capacity



Railway Bridge Monitoring

- New damage detection using Monitoring data
- Several sources of uncertainties removed
- Novel virtual sensing methods developed

Measurement Evaluation of POMs and ANNs

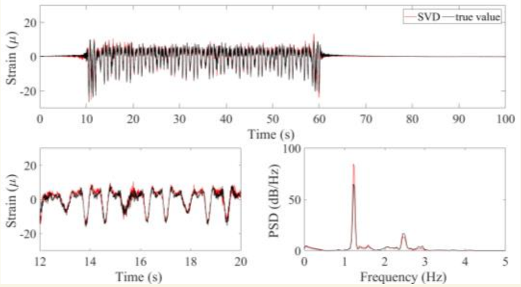


Bridge Load Rating for NDOT

- Completed: protocol for load rating NE bridges
- Low-Cost sensing for experimental load rating

Virtual Sensing for Low-Cost Monitoring

- 3 Virtual Sensing methods developed
- Low-Cost continuous monitoring facilitated



Conclusion, Future Work

- Strain based POMs and ANNs provide robust damage detection methodology compared to other response data
- Automated model updating – in progress
- Environmental effects on POMs, ANNs – in progress

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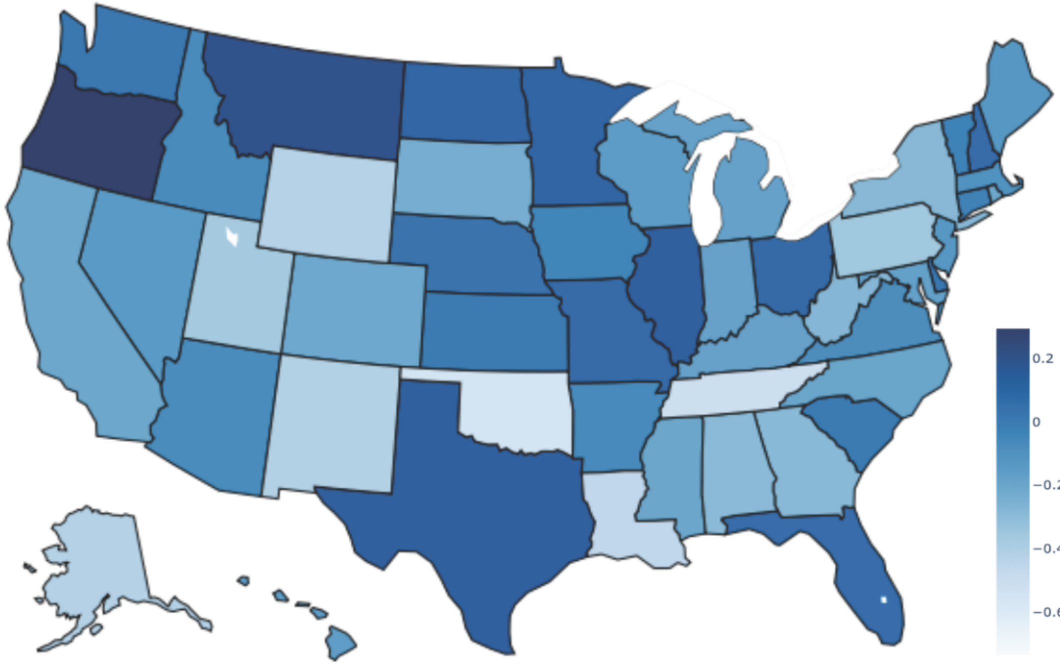
Kale

Lee

UNIVERSITY OF NEBRASKA AT OMAHA

IDENTIFYING THE PREDICTORS OF BRIDGES DETERIORATION IN THE UNITED STATES FROM A DATA SCIENCE PERSPECTIVE

Akshav Kale. Robin Gandhi. and Brian Ricks



BASELINE DIFFERENCE SCORE

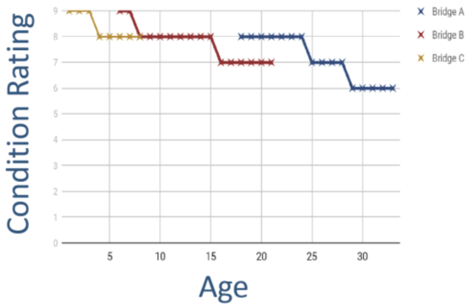
What affects the structural health of the bridges?

#1 Material → Concrete and Prestressed Concrete bridges perform better than Steel and Wooden bridges

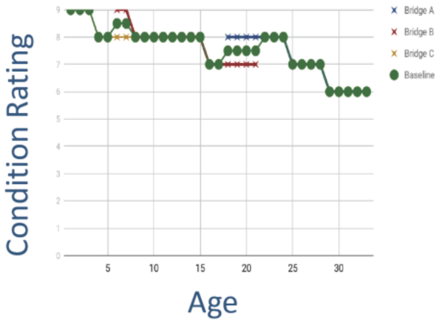
#2 Precipitation → Bridges in Low Precipitation Regions performs better than High Precipitation Region

#3 Region → Performance:
#1 Midwest
#2 West
#3 South
Northwest

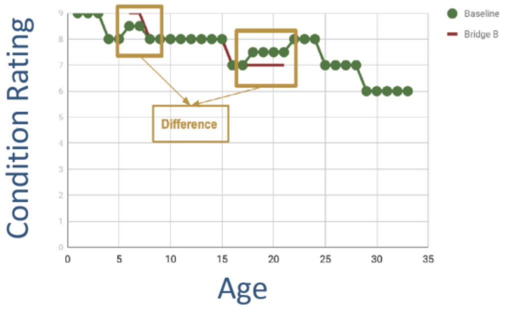
STEP 1: CONDITION RATING OF BRIDGES



STEP 2: COMPUTING BASELINE



STEP 3: AVERAGE THE DIFFERENCES



Lee

Neitzke

Computer-Vision Based UAV Inspection for Steel Bridge Connections

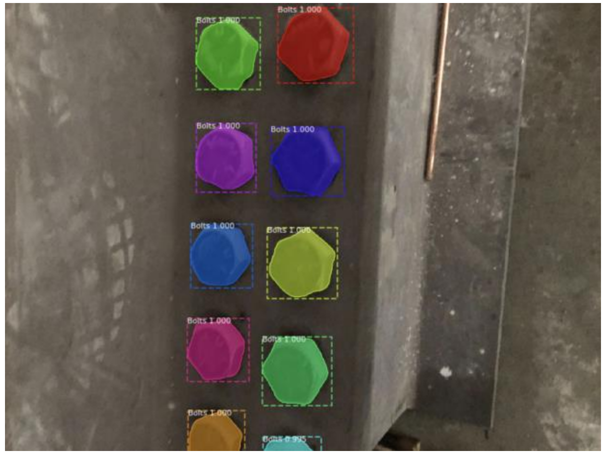
Ji Young Lee, Chungwook Sim, Carrick Detweiler, Brendan Barnes

System for monitoring the health of critical steel bridge connections

1. Data Collection
(From steel bridge with UAV)

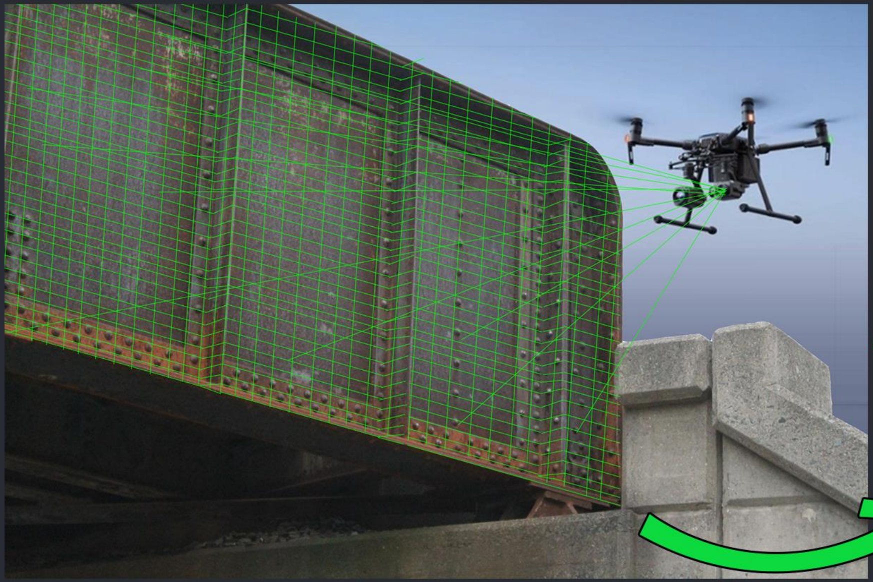
2. Deep Learning
(Instance Segmentation)

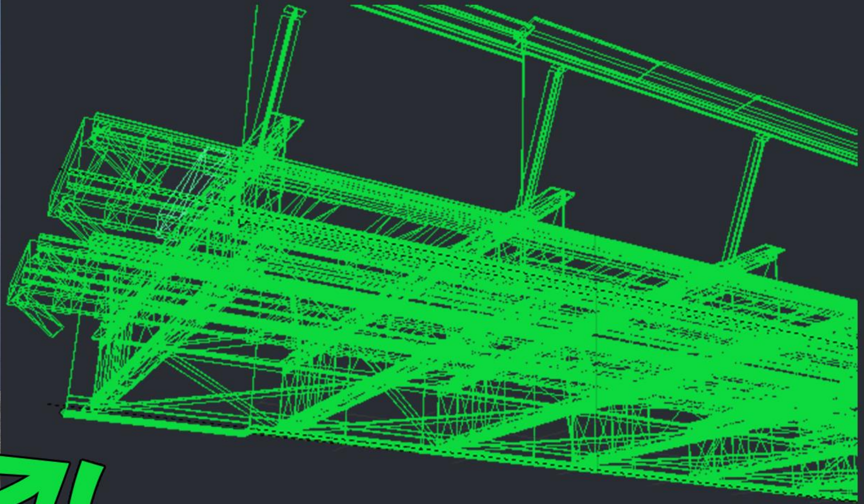
3. Evaluation



Neitzke

Rageh





One idea we are exploring is using a drone to scan a bridge with lidar and photography, then combine the resulting point cloud and photos into a 3D model which can be loaded on the hololens. Once on the hololens, the model can be displayed with various overlays of data related to the bridge, which can be used for training. With current advances in the hololens technology, overlaying the actual bridge in the field, with the holographic bridge and/or data overlays should also be possible, thus providing access to that same information during an on-site inspection.

Rageh

Won

Influence of Modeling Errors on Deficiency Identification in a Steel Railway Bridge Floor System

Ahmed Rageh (Ph.D. Student), Saeed Eftekhar Azam (Ph.D.), Daniel Linzell (Ph.D., P.E., F. ASCE)
University of Nebraska-Lincoln

Problems - Steel Railway Bridges

- Aging
- Large system – bridge AND railway
- Labor intensive condition evaluation

Problems – Condition Evaluation

- **Visual inspection:**
  - ✓ Prescribed frequency
  - ✓ Costly
  - ✓ Subjected to human interpretation
- **Sensors:**
  - ✓ Isolated bridges
  - ✓ Costly

Summary of Past Work And Objectives of Present Work

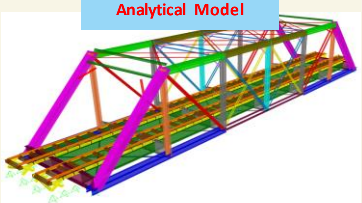
Past

Present

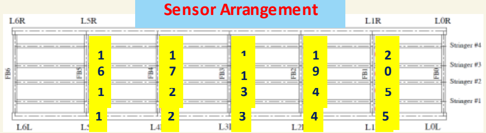
- **Analytical model:** Matlab and SAP2000 OAPI
  - ✓ Models varying in stringer-to-floor beam end fixity
  - ✓ One assumed as a Base Model (i.e., reality)
  - ✓ Other models assumed to have uncertainty
  - ✓ Base model used for training, others for testing
- **Damage feature:**
  - ✓ ΔPOMs shown to be independent of modeling uncertainties

Analytical Investigation

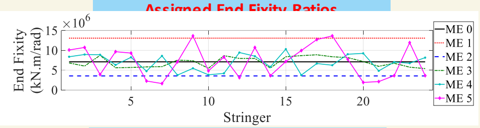
Analytical Model



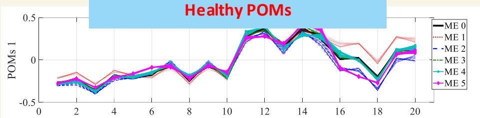
Sensor Arrangement



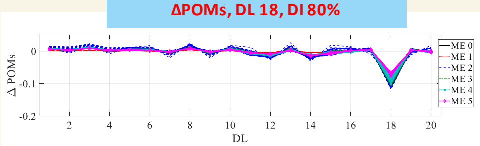
Assigned End Fixity Ratios



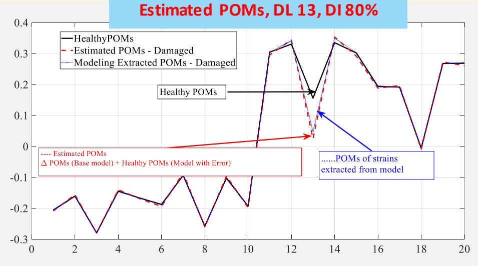
Healthy POMs



ΔPOMs, DL 18, DI 80%



Estimated POMs, DL 13, DI 80%

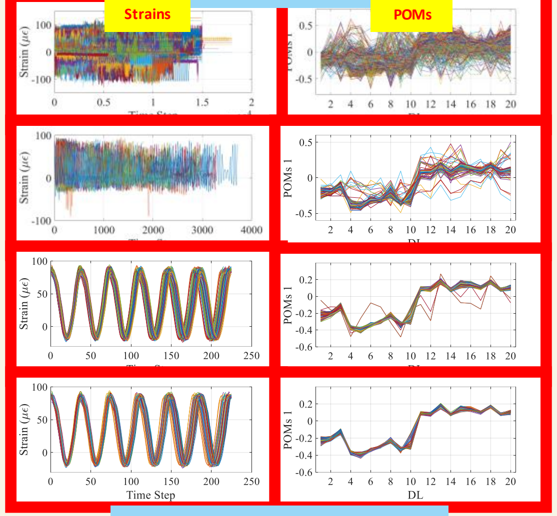


Field Investigation

Deployed Monitoring System

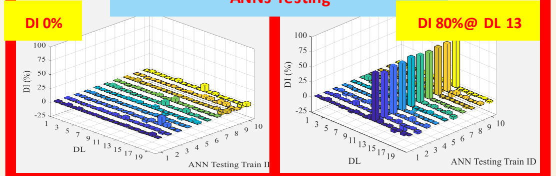
Measured Strains Preprocessing

Strains — POMs



ANNs Testing

DI 0% — DI 80%@ DL 13



Conclusion, Future Work

- Strain based POMs and ANNs provide robust damage detection methodology
- ΔPOMs is a damage robust feature independent of modeling uncertainties
- Environmental effects on POMs, ANNs – in progress

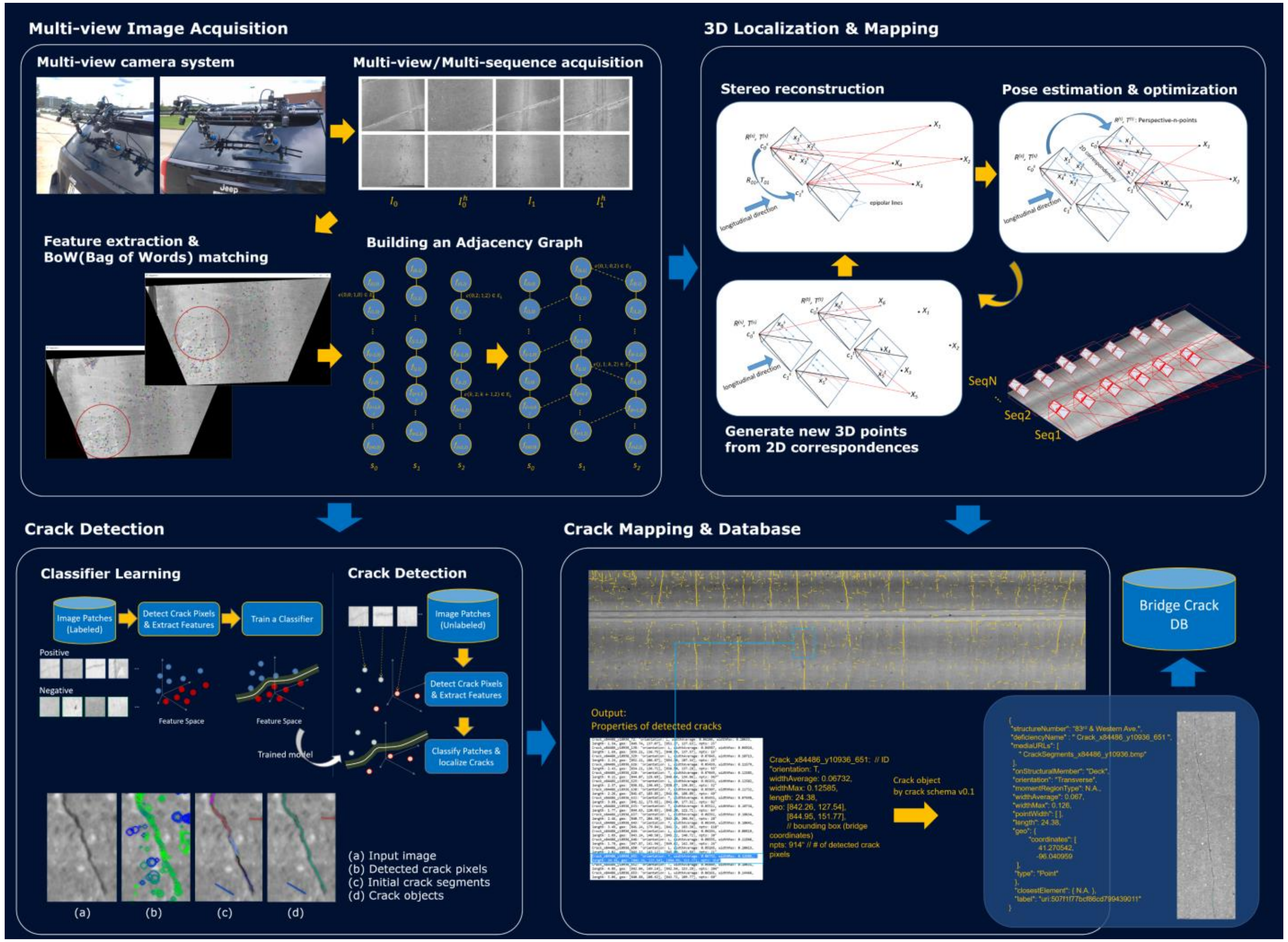
Won

Autonomous Bridge Deck Transverse Crack Detection System with Optical Sensors

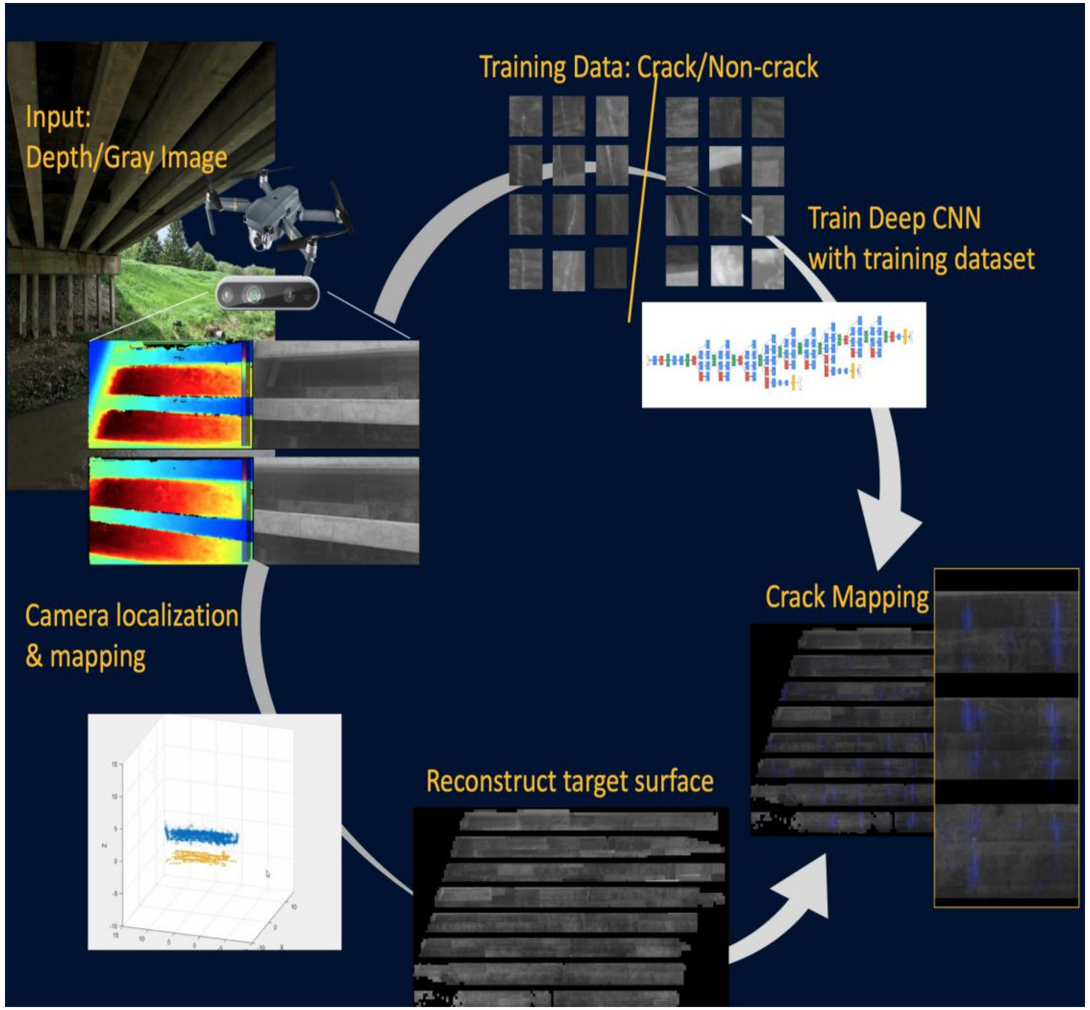
Kwanghee Won and Chungwook Sim

Computer Vision Based Transverse Crack Mapping System

1. Data Collection, Detection, and Crack Database (Bridge Top)



2. Data Collection and Detection (Bridge Bottom)



Enjoy the Session