Using Remote Sensing for Bridge Condition Assessment

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Bridge Condition in the U.S. - $150B to repair today

Settlement

Deck Section Loss

Deteriorated Concrete Element

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MECHANICAL (Global Structural Integrity)		DURABILITY (Local Material Integrity)	
Deflection -Displacement Transducers -- Tiltmeters (rotation) - Seismic (accelerometers) - Laser	**Strain** -Electrical Resistance Gages -Fiber-Optic Gages - Vibrating Wire Gages	**Cracking** - Visual Inspection -Acoustic Emission - Ultrasonic Pulse Velocity - Thermography	**Corrosion** - Half-cell Potential - Acoustic Emission
Thickness - Caliper - Ground Penetrating Radar	**Stiffness** - Seismic (accelerometers) - Displacement Transducers	**Delamination** - Chain Drag - Imact Echo	**Thickness (Cover)** - Ground Penetrating Radar - Impact Echo

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Structural Health Monitoring

- Traditional Inspection Techniques
  - Visual, chain drag, half-cell potential, accelerometers
- Advanced Monitoring Techniques
  - GPR, impact echo, fiber optics, thermal IR, ultrasonic
  - Wireless remote monitoring
- **Remote Sensing: Non-contact data collection**
  - **"***the collection of data about an object, area, or phenomenon from a distance with a device that is not in contact with the object.***"**

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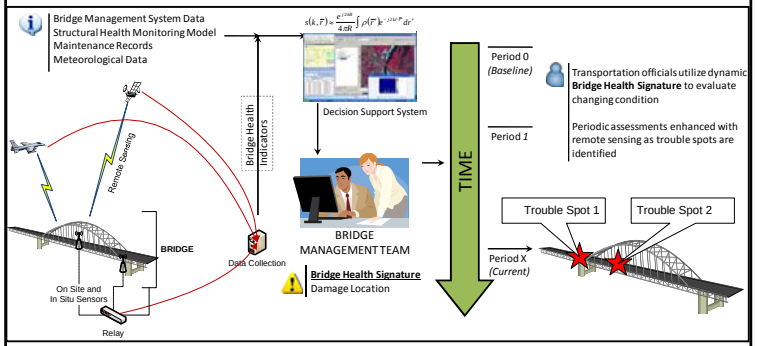
Structural Health Monitoring

- **Remote Sensing for Bridges**
  - Monitor and assess condition, enhance inspection
  - Commercially available technologies
  - At a distance
  - Without stopping traffic or closing lanes

Top Priorities / Challenges

Location	"Top 10" Priorities/Challenges
Deck Surface	Map cracking, Scaling, Spalling, Delaminations (thru surface cracks), Expansion Joint External Issues
Deck Subsurface	Scaling, Spalling, Delaminations , Expansion Joint Internal Issues, Corrosion, Chloride Ingress
Girder Surface	Structural Steel and Structural Concrete Cracking, Paint Condition, Steel or Concrete Section Loss
Girder Subsurface	Structural Concrete Cracking, Concrete Section Loss, Chloride Ingress, Prestress Strand Breakage
Global Metric	Bridge Length, Settlement, Transverse Movement, Vibration, Surface Roughness

Project Concept



Commercial Sensor Evaluation: Performance metrics

- ❑Commercial availability
- ❑Sensitivity of measurement: resolution

- ❑Cost: capital, operational
- ❑Ease of pre-collection prep: structure, equipment
- ❑Ease of data collection and operation
- ❑Complexity of analysis
- ❑Stand-off distance rating
- ❑Traffic Disruption

Promising Technologies

- 3-D Optics including Photogrammetry
- Thermal Infrared
- Digital Image Correlation
- Radar including SAR and InSAR
- Street-view Style Photography
- Satellite Imagery and Aerial Photography
- LiDAR (UNCC)

3-D Optics

Definition: Any digital photography in the optical, thermal infrared, and near infrared parts of the spectrum collected from an aerial, satellite, or other platform

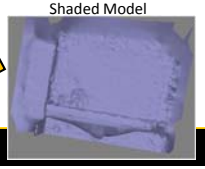
Proposed Application: Mapping bridge features; 3D models; characterizing deck surface (spalling, cracks)

Progress: Laboratory and Field Preliminary Demonstrations

Spalls located under the bridge deck.

Textured Model

Shaded Model



Thermal IR

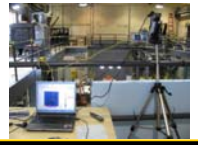
Definition: Measuring the radiant temperature of the concrete deck by thermal infrared camera (anomalies interrupt the heat transfer through the concrete).

Progress: Laboratory demonstrations to investigate surface and subsurface defects

Proposed Application: Locating delaminations and other subsurface defects.

Specimen with simulated defects

Thermal IR Laboratory Setup



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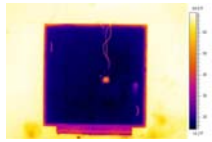

Time-dependent effects

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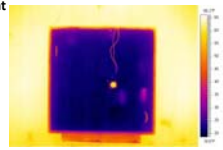
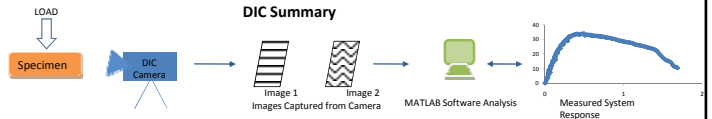


Digital Image Correlation (DIC)

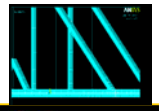
Definition: technique consisting of correlating pixels on optical images to determine variations

Proposed Application: Global response (movement, settlement, vibration); 3D models

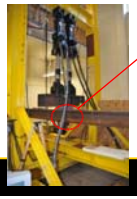


Progress: Preliminary demonstration and applicability validation along with FEA comparison

FEA Model

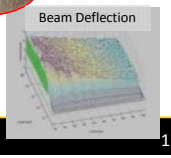


Loaded Steel Beam



Enhanced Tracking Pattern

Beam Deflection



SHM
Project Concept
Remote Sensing
In-Progress

Feasibility/Lab Studies

Imaging GPR - Synthetic Aperture Radar (SAR)

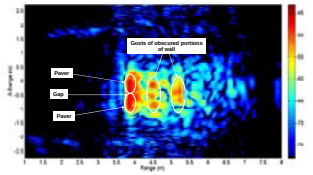
Definition: Coherently process RF backscattering measurements from a moving radar to produce a 2-D (or 3-D) spatial image of scene reflectivity.

Progress: Laboratory demonstrations to investigate surface and subsurface defects

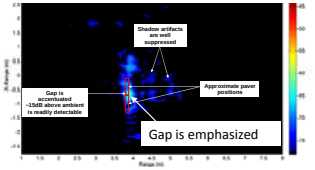
Proposed Application: Mapping bridge surface/sub-surface features; characterize/locate defects (spalling, cracks, delaminations, etc.)

SAR Laboratory Setup

2 Pavers with 1 mm Gap – Background Subtracted



2 Pavers with 1 mm Gap – Change Detection



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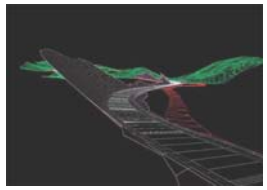
Feasibility/Lab Studies

Interferometric SAR (InSAR)

Definition: InSAR exploits phase differences between 2 or more SAR images to estimate height of features. Comparison of InSAR data from two time periods can detect changes in geometry and/or position

Proposed Application: Bridge dynamics, vibration, and strain; bridge stiffness; **bridge settlement** and/or global changes in position.

Currently: Identified algorithms in literature for change detection processing of InSAR data, i.e. PSInSAR techniques. Evaluating applicability to bridge sensing application. Select bridge to assess if settlement can be measured using imagery separated in time (e.g., did a bridge settle between 2006 vs. 2011?)



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Feasibility/Lab Studies

Street-view Style Photography

Definition: Contiguous collection of geo-located photographs taken from the ground, especially where the photographs have been projected into a continuous 360-degree viewing environment (like Google StreetView).

Proposed Application: Damaged or missing expansion joint seals or plating, cracks and spalls near expansion joints, map cracking, scaling, spalling, and delaminations.

Example image from Google's StreetView showing the underside of a box-beam bridge in Michigan. With higher-resolution panoramas, such an interface could be extremely valuable to bridge inspectors and managers.

Our team's BridgeViewer setup is designed to demonstrate a low-cost, practical example implementable by DOTs.

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Feasibility/Lab Studies

Satellite Imagery and Aerial Photography

Definition: Any satellite imagery and aerial photography in the visible and infrared ranges with sufficient resolution that can be used to remotely assess deck surface conditions

Proposed Application: Use high-resolution imagery to calculate **indices** of deck surface condition, esp. cracking and spalling. We will build from TARUT Study index of road sufficiency calculations via satellite imagery.

Currently: We will be assessing this technology as part of the field demonstrations – ensure careful use of funds if purchasing commercial satellite imagery.

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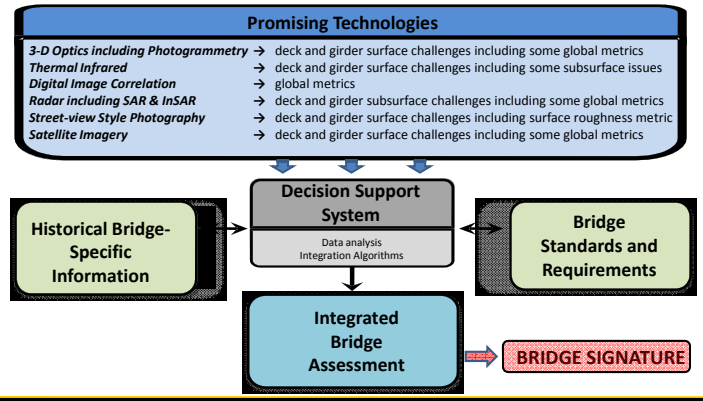
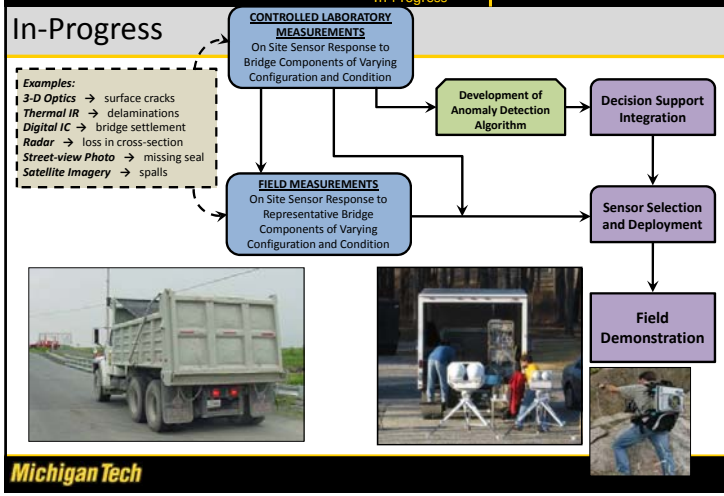
Decision Support System Integration



Decision Support System – key attributes

- DSS needs to be able to integrate, interpret, and present data that is usable by non-experts
- Extract features of interest and indicators of bridge condition
- Compare remote sensing results to expected / normal results and detect anomalous results, especially change (based on previously-collected data or modeled results)
- Should be accessible in the field (durable tablet) and for mission planning and repair prioritization
- Will use example data to produce most usable, practical DSS that meets needs of bridge community

In-Progress



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Project Team / Disclaimer

- Project Team Members: MTTI + MTRI + CAR

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Thank You

www.mtti.mtu.edu/bridgecondition/

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