Remote Sensing Technologies for Detecting Bridge Deterioration and Condition Assessment

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Michigan Tech | CAR | Department of MDOT Transportation

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

Settlement

Deck Section Loss

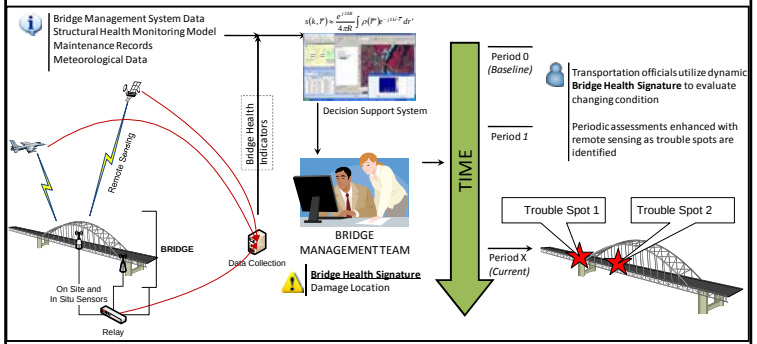
Deteriorated Concrete Element

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

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.***"**

Project Concept



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

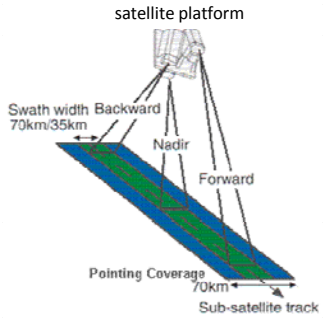
Project Goals

- Establish remotely sensed bridge condition "signature"
  - Assess the potential for commercial remote sensors to be used to assess bridge condition and performance
  - No lane closures, no traffic disruption, no contact with bridge
- Provide bridge inspectors with data to enhance inspection processes
  - Provide condition monitoring between required inspections
- Create the framework for a decision support system to prioritize needs
  - Correlate **on-site**, **in-situ**, and **stand-off** sensors with conventional assessment methods, historic bridge information, and bridge standards and requirements

Electro-Optical Imagery

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)

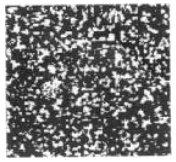


Speckle Photography and Speckle Pattern Interferometry

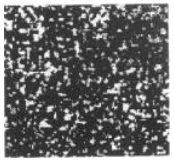
Definition: Speckle patterns are high-contrast, fine-scale, granular patterns produced by light reflected from optically rough surfaces.

Proposed Application: Interferometry of speckle patterns produces fringes from which ***deformations or displacement gradients (strain)*** can be inferred.

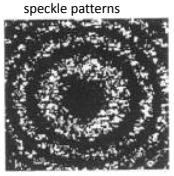
Speckle pattern of undeformed surface



Speckle pattern of deformed surface



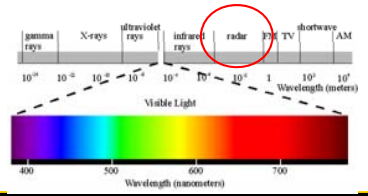
Difference of the two speckle patterns



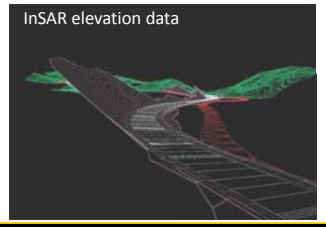
Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR)

Definition: SAR collection uses multiple radar (electromagnetic [radio] wave reflections) returns from small(er) antennae to simulate one radar measurement from a single, large antenna; ***increases effective resolution***.

Proposed Application: Bridge dynamics, vibration, and strain; bridge stiffness; bridge settlement



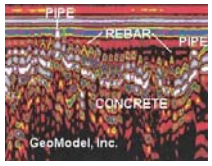
InSAR elevation data

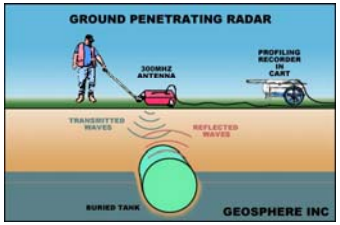


Ground-Penetrating Radar (GPR)

Definition: Depth sounding by radio waves emitted over a wide frequency band either continuously or in discrete pulses as an antenna sweeps the ground.

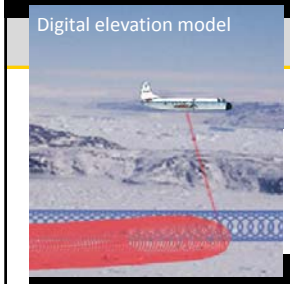
Proposed Application: Characterization of deck subsurface; detection of delaminations, voids, etc.





LiDAR / Laser Scanning

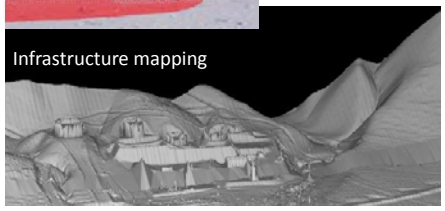
Digital elevation model



Definition: 3D mapping (scanning) of surfaces or objects by timing the reflection of millions of laser pulses.

Proposed Application: 3D modeling; detecting bridge displacement; measuring size and shape of features

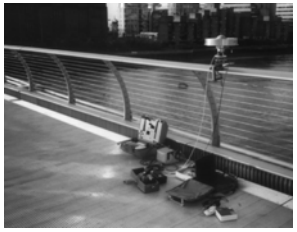
Infrastructure mapping



GPS/Geodetic Measurement

Definition: Use of precision measurements of position to determine movement over time

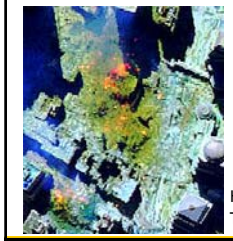
Proposed Application: Absolute displacement measurements of structural elements; measuring bridge length



Infrared Thermography and Spectroscopy

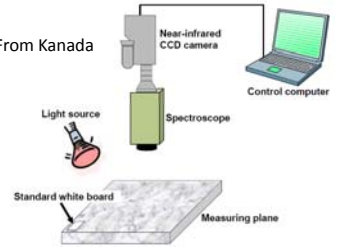
Definition: Images collected in thermal infrared spectrum from which features are identified by their size/shape (thermography) or their spectral content (spectroscopy)

Proposed Application: Locating delaminations and other subsurface defects



Hot Spots at World Trade Center

From Kanada

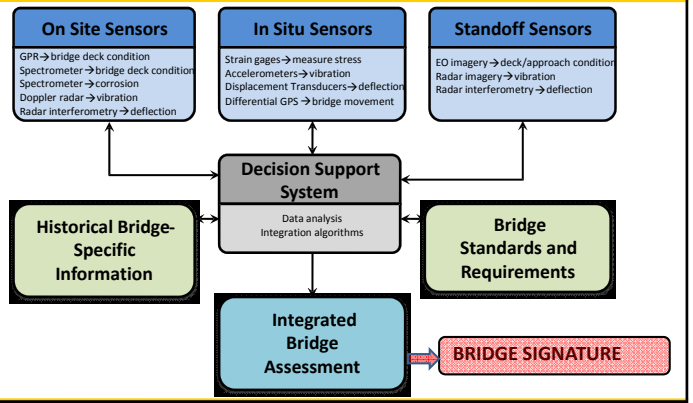


Commercial Sensor Evaluation: Performance metrics

- ❑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

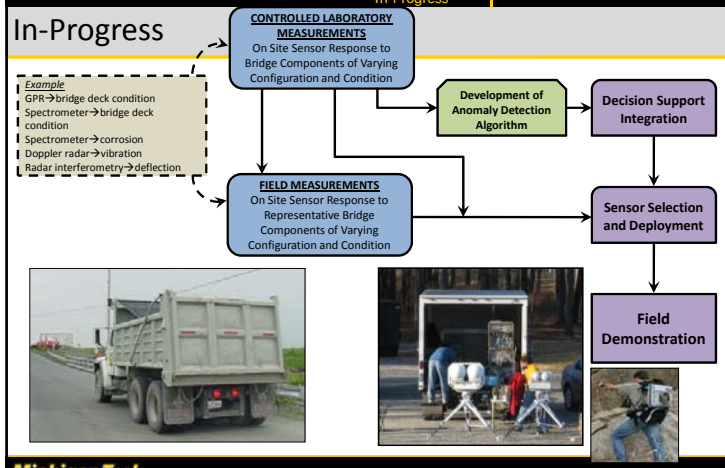
Decision Support System Integration



SHM
Project Concept
Remote Sensing
In-Progress

Commercial Sensor Evaluation
Decision Support System
Field Demo

In-Progress



Acknowledgements

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Thank You

www.mtti.mtu.edu/bridgecondition/

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