Bridge Condition Assessment Using Remote Sensors

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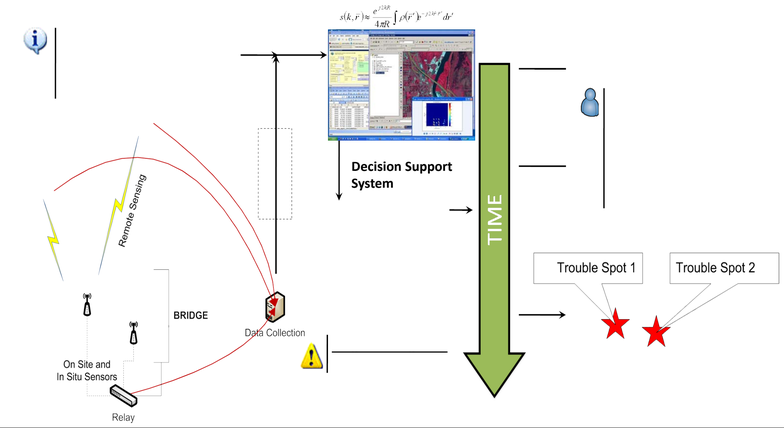
Introduction

The condition of transportation infrastructure, specifically bridges, has received a great deal of attention in recent years as a result of catastrophic failures, deteriorating conditions, and even political pressure. The U.S. is home to over 600,000 highway bridges. The number of bridges listed as structurally deficient as of 2009 was 71,179 (11.8% of U.S. highway bridges), clearly demonstrating the need for a decision support and management system to ensure the correct bridges receive the necessary and needed funding.

The objective of structural health monitoring is to observe infrastructure condition, assess in-service performance, detect deterioration, and estimate remaining service life. In this research the feasibility of using commercial remote sensing technologies such as Doppler radar, ground penetrating radar, digital image correlation, and interferometry is being explored for bridge condition evaluation. An assessment is underway to explore how these techniques could be combined with current practices to assess current bridge condition and health to support and promote inspection, maintenance, and repair decisions.

Bridge Health Monitoring Concept



Goals and Impacts

- Establish remotely sensed bridge health indicators
- Develop unique bridge condition "signature" for baseline performance characterization
- Create the framework for a decision support system to prioritize needs
- Enhance current bridge inspection practices using commercial remote sensing and spatial information
- Provide method for expedited discovery of bridge health concerns
- Evaluate cost-effectiveness of remote sensing for bridge inspections

Bridge Challenges

- In reinforced and prestressed concrete: systems cracking, scaling, delamination, spalling, chloride contamination, efflorescence, ettringite formation, honeycombs, pop-outs, wear, collision damage, abrasion, overload damage, and reinforcing and prestressing steel corrosion
- In steel members: corrosion, fatigue cracking, overloads, collision damage, heat damage and paint failures


Corrosion and Section Loss


Deteriorating Bearing


Steel Fatigue


Settlement

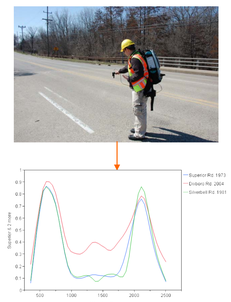

Deteriorated Concrete Element


Delamination with Patching

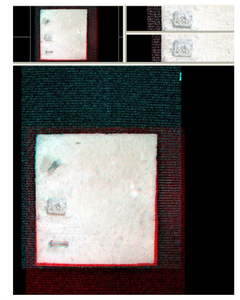
Examples of Remote Sensing Technologies for Bridge Condition Assessment

1. Electrical-Optical Imagery (EO) - are imaging sensors which are sensitive to electromagnetic radiation (reflected light) in the visible and near-infrared parts of the spectrum. Aerial photographs, satellite images, and local measurements of spectral reflectance are examples of EO imaging.
   - Proposed Application for Condition Assessment: These technologies might be useful for the characterization of bridge deck surface condition including spalling, cracking and crack density, and surface ride quality, as well as paint condition assessment for steel structures.
2. 3-D Stereoscopic Photogrammetry - a deterministic 3-D image created from photographs; 3-D image created using 60% overlap between photograph pairs.
   - Proposed Application for Condition Assessment: This technology will be used for measuring the location, number, size, and depth of spalls on bridge deck surface.
3. Radar and Interferometric Synthetic Aperture Radar (Radar and SAR) - the illumination by and reflection of radio waves which contain information on a target's motion and material composition; high-resolution deformation over time can be measured with SAR and internal features in bridges can be seen with radar.
   - Proposed Application for Condition Assessment: These technologies might be useful for measurement of bridge displacements and accelerations for vibration response correlation.
4. Ground Penetrating Radar (GPR) - method of obtaining information on buried targets and subsurface layers from short time-duration radar pulses.
   - Proposed Application for Condition Assessment: Some potential applications of GPR for structural concrete include: thickness estimation from one surface, the location of reinforcing bars or other metallic objects, estimation of the depth of buried objects, location of moisture variations, location of voids, the dimensions of such voids, location of honeycombing or cracking, and an estimation of the size of reinforcing bars. For this project, GPR might be useful for bridge deck sub-surface condition including delamination, location and condition of reinforcement, as well as anomaly detection.
5. Infrared Thermography and Spectroscopy (IR) - the detection of electromagnetic waves in the mid-infrared "thermal" part of the spectrum; different thermal patterns in a bridge deck.
   - Proposed Application for Condition Assessment: This technology might be useful for the evaluation of deck delaminations at highway speeds, thus eliminating the need for lane closures.

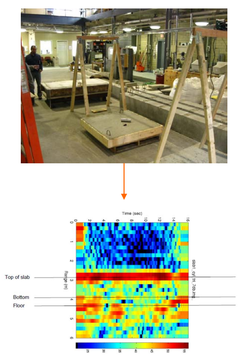
Spectral reflectance of bridge surfaces



3-D Photogrammetry



Preliminary test of slab with radar

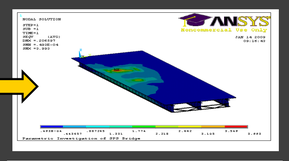


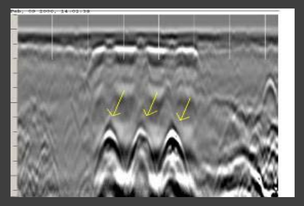
Critical Tasks

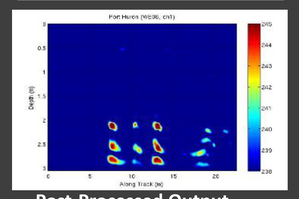
Task A – Bridge Condition Assessment
- Develop a State of Practice Report (now avai website)
- Laboratory Investigation/Demonstration
- Structural Simulation

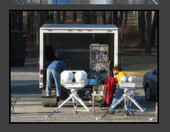
Task B – Commercial Sensors Evaluation
- In situ sensor evaluation
- On site sensor evaluation
- Standoff remote sensor evaluation

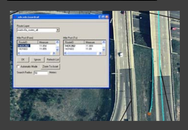
Task C – Decision Support System
- Create software to store bridge reference information
- Write software code to integrate and archive diverse sensor data from on site, in situ, and stand off remote sensors
- Develop normalcy models for sensor response
- Implement and test algorithms for fusing current sensor data and historical information
- Apply sensor algorithms to results from sensor evaluations
- Create a beta version of the DSS for testing and evaluation
- Demonstrate capability of DSS to create integrated bridge assessment




Raw GPR Output


Post-Processed Output

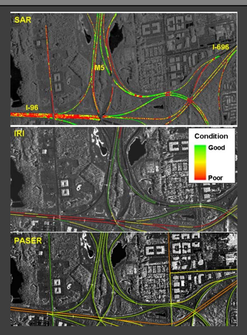




Task D – Field Demonstration
- Site identification
- Field implementation

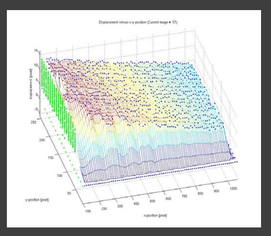
Task E – Assessment
- Technical assessment and evaluation analysis of the DSS tools
- Economic valuation and assessment of the cost-effectiveness of the bridge monitoring system
- Comprehensive project review and assessment workshop at Michigan Technological University

Bridge Inspection
Left – Devin Harris (MTU) and Jason DeRuyver (MDOT) review an MDOT bridge safety inspection report.
Center – Expansion joint with debris and spalling.
Right – Steel beam that has been severely bent after a truck collision.



Comparison of airborne SAR speckle contrast with IRI and PASER data at the intersection of M5/I96/I696


Digital Image Correlation Experiment: Steel beam mounted to be deflected


Digital Image Correlation Experiment: Image produced during load change

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