Measuring and Communicating Bridge Performance with Remote Sensing Technologies

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Presentation Outline

• Project Concept
• Remote Sensing Technologies and Field Demonstration
• Decision Support System
• Moving forward
Bridge Condition in the U.S. > $150B to repair today

Settlement

Corrosion and Section

Deteriorated Bearing

Deteriorated Concrete Element
**Remote Sensing** – for bridge engineers: enhanced bridge inspection at highway speed without traffic disruption (e.g. collecting information at a distance)

- Bridge Management System Data
- Structural Health Monitoring Model
- Maintenance Records
- Meteorological Data

**Bridge Health Indicators**

![Diagram](image)

**Decision Support System**

- Bridge Health Signature
- Damage Location

**Transportation officials utilize dynamic Bridge Health Signature to evaluate changing condition**

**Periodic assessments enhanced with remote sensing as trouble spots are identified**

- Period 0 (Baseline)
- Period 1
- Period X (Current)

**Trouble Spot 1**

**Trouble Spot 2**
**Technology Selection**

<table>
<thead>
<tr>
<th>Location</th>
<th>Applicable Technologies</th>
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<tr>
<td>Surface</td>
<td>3-D Optics, Street-view Style Photography (GigaPan &amp; BVRCS), LiDAR,</td>
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<td>Subsurface</td>
<td>Infrared Thermography (Thermal IR), Ultra Wide Band Imaging Radar System (UWBIRS)</td>
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<tr>
<td>Global System</td>
<td>Digital Image Correlation, LiDAR, Interferometric Synthetic Aperture Radar (InSAR)</td>
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*Technology Selection:* commercially available technologies to enhance current inspection processes, including safety, while minimizing traffic disruption.
Deployment on Willow Road over US-23 during August 2011 field demonstrations

Visual of percent spalled area for the Willow (6.99% spalled) Road bridge using 3DOBS data as the input and ArcGIS as the analysis software
3DOBS

• Benefits
  – Low cost components, rapid deployment, limited time to collect data
  – Useful metrics: % area and volume & location of spalls, International Roughness Index (IRI)

• Limitations
  – Speed of collection, 5mm resolvable features (with current deployment; capable of higher-resolution)

• Implementation
  – Near user ready, value added metrics aligned with current bridge rating process, automation of analysis
Deployed on Freer Rd to capture a bridge photo inventory

location of the digital photographs being displayed in Google Earth; each box contains a hyperlink to a full-resolution view of the photo taken at that location
Profile view of Willow Rd from a GigaPan image. The full resolution version of this photo captures the entire side of the bridge.
StreetView Style Photography (BVRCS, GigaPan)

• Benefits
  – Low cost components, rapid deployment, limited time to collect data
  – Useful metrics: easily viewable geo-tagged photo inventory, can compare condition over time with multiple inventories

• Limitations
  – Automation of analysis, not yet at highway speed, GigaPan storage

• Implementation
  – Very close to user ready, “how to deploy” manual
Thermal IR

Bridge deck delamination map created by thermal IR images and output data

Optical and Thermal Image highlighting observable subsurface defect
Thermal IR

• Benefits
  – Useful metrics: % delamination, detects subsurface defects
  – Qualitative and quantitative assessment tool

• Limitations
  – Collection time, camera specifics, data processing and user interpretation, cost

• Implementation
  – Near user ready, Advanced equipment, “how to deploy” manual
Ultra Wide Band Imaging Radar System (UWBIRS)

Lateral translator and radar equipment. Such a system could be adapted for use on a moving vehicle.
Ultra Wide Band Imaging Radar System (UWBIRS)

• Benefits
  – Potential for useful metrics: % spall and delamination, detects surface and subsurface defects

• Limitations
  – Data processing and user interpretation, cost

• Implementation
  – Advanced equipment, further development to 3D
Digital Image Correlation

**Laboratory set-up**

Scaffolding setup at Mannsiding Rd. bridge facing exterior girder with speckle patterns
Digital Image Correlation

• Benefits
  – Can track changes in mechanical behavior over time
  – Useful metrics: remotely captures deflection, strain field and vibration (global system metric)

• Limitations
  – Environmental effects: error induced by wind and traffic flow, more ideally suited in current form for controlled environments

• Implementation
  – Not recommended for deployment without significant technology improvements, consideration of complementary technologies (LiDAR)
Composite LiDAR intensity and elevation image.

- Surface condition (% spalled, location & volume of spalls, related metrics)
- Global features (e.g. static deflection, high load)
LiDAR

• Benefits
  – Some DOTs own equipment for non-bridge assessment activities (familiarity with technology) or have contract access to it – just a new deployment
  – Useful metrics: Deck condition (% spalled and surface condition) and Global metrics (static deflection and clearance)

• Limitations
  – High capital cost, speed of deployment, appropriate integration in bridge condition assessment framework

• Implementation
  – Close to user ready, “how to deploy” manual
Decision Support System

- Bridge Condition data in GIS format
- Web-based interface
- Support bridge management team
- Useful for understanding bridge condition
- Accessible via ruggedized tablets in the field
Geo-tagged photographs from the BVRCS are available as a Points layer in Bridge GIS.
- DSS now uses Pontis schema; more portable & updateable
- Bridge condition data is more easily accessible for users, including mapping & custom queries

Individual bridge data along with remote sensing results are made available through the DSS
Decision Support System and Result Integration

- Input remote sensing data can be integrated to create a bridge deck health signature

- Ex: % spalled, % delaminated, roughness

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**INPUT DATA**
- Bridge Viewer Photos
- Gigapan Photos
- High-res Photo Composite
- Radar (Deck)
- Digital Elevation Model (DEM)
- DEM Standard Deviations
- Hillshade
- Thermal IR
- Delaminations
- Spalls

**SUMMARY DATA**
- brkey
- spall (%), sensor
- delamination (%), sensor
- roughness, IRI score
- crack count, crack density
- deflection amount
- settlement
- comprehensive bridge signature

**Concept diagram for remote sensing datasets and their role in the DSS.**
Closure

• Determining value-added measures from remote sensing results:
  – e.g. % spall in wheel paths or relative to joints
  – Aligning data analysis with advanced DOT judgments
  – Establishing a unique bridge signature

• Closing the gap between technology, demonstrations and DOT use
  – DOT and industry collaborations
  – DOT buy-in nationwide (quantifiable, reliable)

• Refining the “How-to” manuals for DOT use
  – Guides on how to implement & use these technologies
Project Team / Disclaimer

- **USDOT – Research and Innovative Technology Administration**
  - Commercial Remote Sensing and Spatial Information
  - Program Manager: Caesar Singh
  - Cooperative Agreement #DTOS59-10-H-00001
  - Project: Bridge Condition Assessment Using Remote Sensors

- **Project Partners**
  - Michigan Department of Transportation
  - Michigan Tech Transportation Institute
  - Michigan Tech Research Institute
  - Center for Automotive Research

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Bridge Condition Assessment Using Remote Sensors

Project Title: Bridge Condition Assessment Using Remote Sensors
Sponsoring Organization: USDOT Research and Innovative Technology Administration (RITA)

Michigan Technological University’s Michigan Tech Transportation Institute (MTTI) and Michigan Tech Research Institute (MTRI), in cooperation with the Center for Automotive Research and the Michigan Department of Transportation, are undertaking a project for the USDOT Research and Innovative Technology Administration that will explore the use of remote sensing technologies to assess and monitor the condition of bridge infrastructure and improve the efficiency of inspection, repair, and rehabilitation efforts. This investigation will build on existing work that places sensors directly on the bridge structure to assess deterioration and damage.

Remote sensing technologies will be correlated with in-place sensors to obtain bridge condition assessment data without the need to place heavy instrumentation on the structure. This information will then be analyzed by a computer decision support system to develop unique signatures of bridge condition. Monitoring how these signatures change over time will provide state and local engineers with additional information used to prioritize critical maintenance and repair of our nation’s bridges. The ability to acquire this information remotely from many bridges without the expense of heavy sensor networks will provide more accurate and near real-time assessments of bridge condition. Improved assessments allow for limited resources to be better allocated in repair and maintenance efforts, thereby extending the service life and safety of bridge assets, and minimizing costs of service-life extension.

NEWS
November 29, 2010 - Ann Arbor.com, “Washtenaw County’s bridges in trouble, lack of state funding cited for inability to maintain or replace them.”

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