Automatic Vision Based Probabilistic Condition Assessment of Bridges

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Problem Statement

Delamination

Section loss

Corrosion

Concrete cracking and corrosion

Concrete spalling and exposed reinforcement

Defect	CS 1 Good	CS 2 Fair	CS 3 Poor	CS 4 Severe
Delaminations/ Spalls/Patch Areas (1080)	None	Delaminated. Spall 1 in. or less deep or less than 6 in. diameter. Patched area that is sound.	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is unsound or showing distress. Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or bridge; OR a structural review has been completed and the defects impact strength or serviceability of the element or bridge.
Exposed Rebar (1090)	None	Present without measurable section loss.	Present with measureable section loss, but does not warrant structural review.	
Cracking (RC) (1130)	No cracks. Hairline cracks not requiring sealing, or cracks that have been sealed.	Unsealed cracks of narrow width, or unsealed minor to moderate pattern/map cracking. Where efflorescence is present, it's minor with no evidence of rust staining.	Unsealed cracks of medium to wide width, or extensive pattern map cracking. Where efflorescence is present, there is heavy build-up and/or rust staining.	

Concrete Cracks			
Crack Widths		Crack Density or Spacing	
Hairline	<0.012"	Minor	>3 feet
Narrow	0.012" up to 0.05"	Moderate	1 to 3 feet
Medium	0.05" up to 0.1"	Extensive	<1 foot
Wide	>0.1"		

Figure 1. Even a defect with small dimensions (0.05-0.1") comes under the category of wide cracks, which can be critical and warrant a poor or worse ratings

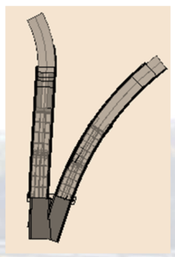
Uncertainties associated with sensing technologies, sensing environments, modeling and detection can impact condition assessment

Element	Activity	SO Criteria
Deck	Joint Replace or Repair	More than 1% in condition state 3 or 4
	Minor Deck Rehabilitation or Repair including Deck Overlay	Element in condition state 3,4 or 5
	Crack Sealing or Patching	Surface in condition state 4 or 5
	Bridge Washing	All functional structures (every 2 years)
Super-structure	Bearing Area Restore or Replace / Bearing Lubrication	Steel bearings in condition state 3, 4 or 5
	Seismic Retrofit	Bridge in a Seismic Acceleration Zone of 0.10 (10%) or greater by the 1996 USGS
	Replace or repair damaged substructure	Element in condition state 3, 4 or 5
	Scour remediation / Scour countermeasures	Scour code of 3 or less
Painting	Bridge Painting (full, zone, and spot)	More than 25% in condition state 3,4 or 5

Fig2. If condition ratings are assigned based on erroneous measurements, this can directly impact preventive maintenance actions, and thereby bridge life cycle costs as well as safety issues

Research Vision

Registered point cloud



Bridge Information Model (BrIM)

Images showing defects

Uncertainty Representation Model, NBE Defect Specification

Defect identification and quantity estimation A0

- Extract defect and uncertainty quantities
- Tag the quantities with BrIM elements

Enriched as-is BrIM with defect and uncertainty details

NBE Element Specification – Rules encoded in as-is BrIM

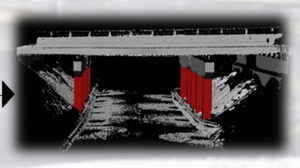
Uncertainty propagation estimation and condition assessment A1

- Quantify condition beliefs at element level, at component level, and at the overall bridge level

Example: $CR_{Component}$(Substructure) = {(CS1*, 24.00%), (CS2, 12.83%), (CS3, 51.92%), (CS4, 02.63%), (*Unknown*, 08.62%)}

Condition ratings (CR) with beliefs

Color coded Visualization A2



- Add condition ratings and beliefs to BrIM element metadata
- Query and visualize in 3D

Research Objectives

1. Determine a methodology to represent (at defect-level, element-level and system-level) and account for different types of uncertainties arising due to data collection, pre-processing and modeling

2. Determine a technique to translate information from images and laser scans into condition ratings; identify existing uncertainties with reasonable precision and recall, as well as accurately quantify identified uncertainties

3. Determine under what conditions does probabilistic assessment work better than deterministic approaches by leveraging information from images/scans and data capture context

Research Method

1. Case studies using real bridge (scan and image data + 3D model) and with simulated data

2. Prototype development and testing to incorporate uncertainty representation model and reasoning mechanism to deal with uncertainty accumulation

3. User studies – To generate ground truth for validating probabilistic reasoning mechanisms