

Improving Bridge Assessment through the Integration of Conventional Visual Inspection, Non-Destructive Evaluation, and Structural Health Monitoring Data

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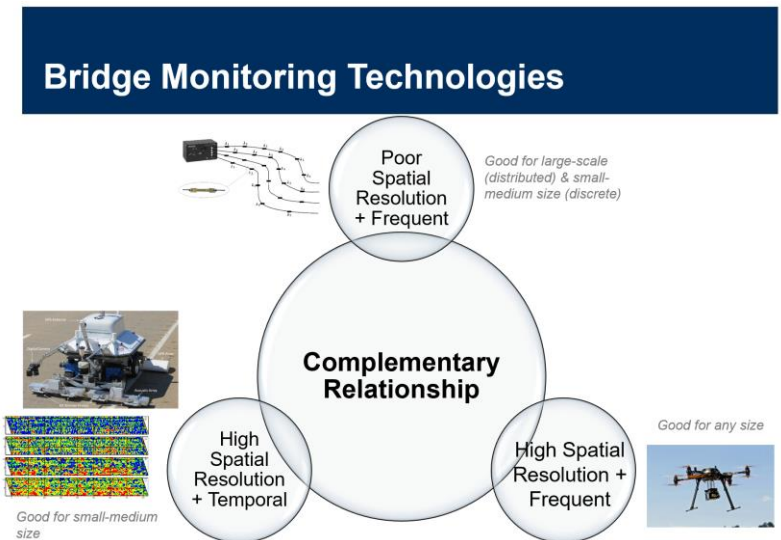
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The Research Problem

- ❑ Large costs and relatively long intervals between inspections for large scale of civil infrastructure systems caused by access issues
- ❑ Current assessment approaches are generally subjective in nature and provide only qualitative data reflective of surface or near-surface condition
- ❑ Huge gap exists in the establishment of effective approaches to fuse the collected massive NDE and SHM data
- ❑ A more comprehensive integration framework to integrate the results taken from NDE/SHM/visual inspection is needed

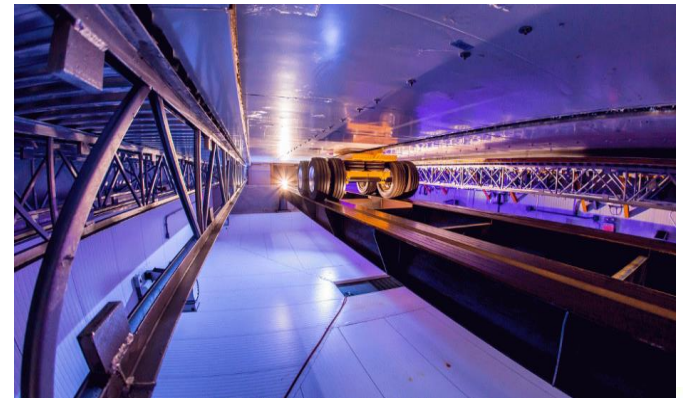


Project Objectives

- ❑ Establish a framework capable of leveraging emerging SHM and NDE techniques to provide improved performance assessment of bridges

- ❑ Addressing the principal challenges associated with studying the service life of bridge structures:
 - Long-time scales (which requires accelerated aging)
 - The diverse outputs related to bridge condition (in terms of data collected through SHM, NDE, and visual inspection)

- ❑ Identifying the synergies among bridge degradation, remaining service life, and the results taken from the multimodal sensing technologies (SHM, NDE, and UAV-based)



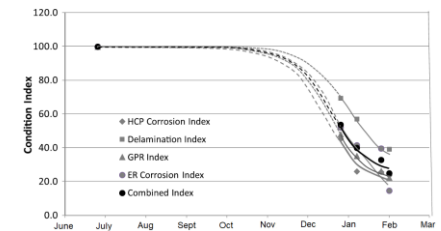
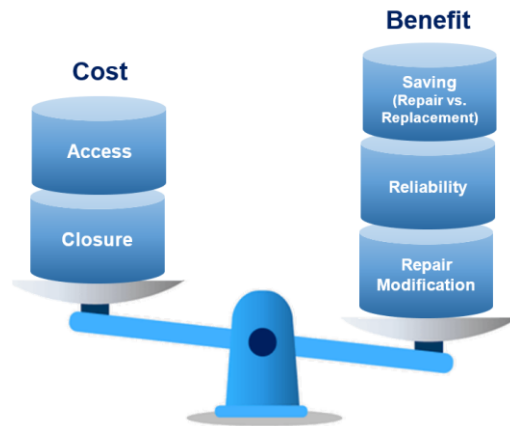
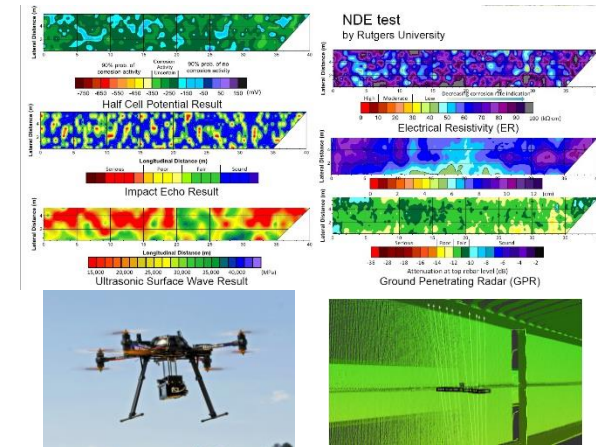
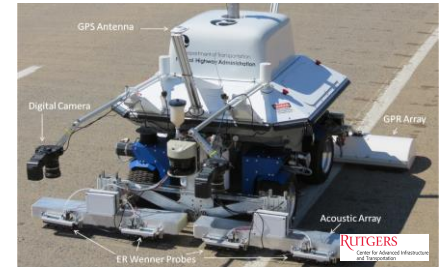
Project Approach/Deliverables

Tasks:

- ❑ Collection of High-Resolution and High-Temporal Data from the BEAST Specimen
- ❑ Processing of Collected Data
- ❑ Advanced Statistical Data Analytics
- ❑ Development of Recommendations

Deliverables:

- ❑ Final Report
- ❑ Technical Articles
- ❑ Technical Events (TRB, NEBPP)



Schedule/Status

- ❑ The start dates for the project was December 1, 2019
- ❑ Due to COVID-19 pandemic, the Rutgers BEAST operation paused since March 1, 2020
- ❑ The second round of data obtained from the BEAST testing facility showed no deterioration after exposing the specimen to 800K loading cycles
- ❑ Th team acquired massive bridge deck deterioration data from Utah State University and the University of Waterloo, as well as concrete structures in Pittsburgh
- ❑ A vision-based crack, spall and delamination detection software program has been developed accordingly^{1,2}
- ❑ The BEAST or any other bridge deck data could be feed into the algorithm directly

Months	Year 1				Year 2			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Task 1: Collection of Data from the BEAST Specimen								
Task 2: Processing of Collected Data								
Task 3: Advanced Statistical Data Analytics								
Task 4: Development of Recommendations								
Draft Final Report								
Final Report								

¹ Q. Zhang, K. Barri, S. K. Babanajad, A. H. Alavi, "Real-Time Detection of Cracks on Concrete Bridge Decks Using Deep Learning in Frequency Domain" Subjected to Minor Revision, Engineering, Elsevier, 2020. (Impact Factor: 6.495)

² Q. Zhang, L. Ruzzi, T. Macioce, F. Moon, A. Alavi, "Automated Detection and Quantification of Cracks and Spalls in Concrete Structures Using Deep Learning" To be Submitted to TRB 2021.

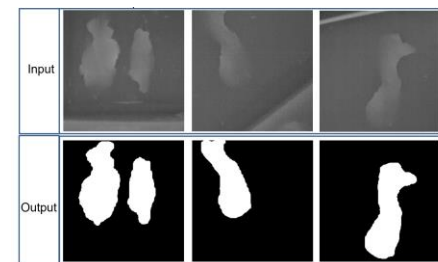
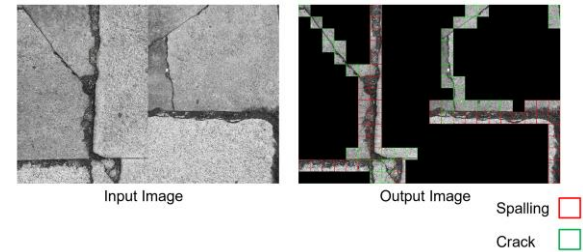
Application of Research Results

- ❑ Pitt Bridge Condition Assessment System (PittBCAS): Automated detection and quantification of cracks, spalls and delamination in concrete structures using deep learning
- ❑ Spalling and delamination densities are the two main parameters in the current PennDOT rating system for concrete bridge decks
- ❑ The crack density is also most useful for the prediction of useful life of bridge decks
- ❑ Images taken manually by the PennDOT personnel or via their UAVs can readily be fed into the PittBCAS software to calculate the densities of the cracked, spalled and delaminated areas
- ❑ The calculation speed is about 5 seconds per square foot of the deck

Condition Rating for Concrete Bridge Deck Evaluation:

Category Classification	Rating	Condition Indicators					
		Deck Area		Electrical Potential	Deck Area	Chloride Content (#/CY)	Deck Area
		Visible Spalls	Delamination				
Category #3 Light Deterioration	9	none	none	0.0	none	0	none
	8	none	none	$0.0 < E.P. < 0.35$	none	$0 < C.C. < 1$	none
	7	none	$< 2\%$	$0.35 < E.P. < 0.45$	≤ 5	$0 < C.C. < 2$	none
Category #2 Moderate Deterioration	6	$< 2\%$ spalls or sum of all deteriorated and/or contaminated deck concrete ($\geq 2\# / C.Y. Cl$) $< 20\%$					
	5	$< 5\%$ spalls or sum of all deteriorated and/or contaminated deck concrete 20% to 40%					
Category #1 Extensive Deterioration	4	$> 5\%$ spalls or sum of all deteriorated and/or contaminated deck concrete 40% to 60%					
	3	$> 5\%$ spalls or sum of all deteriorated and/or contaminated deck concrete $> 60\%$					
Structurally Inadequate Deck	2	Deck structural capacity grossly inadequate					
	1	Deck has failed completely - Repairable by replacement only					
	0	Holes in deck - Danger of other sections of deck failing					

Notes: Rating 9 - No deck cracking exists. Rating 8 - Some minor deck cracking is evident



Pitt Bridge Condition Assessment System (PittBCAS)



Click to open the interface for
Crack and Spall Evaluation

Click to open the interface for
Delamination Evaluation

Crack and Spall Evaluation

The screenshot shows a software window titled "Crack and Spall Evaluation". The interface is divided into two main sections: "Input Setup" and "Output Results".

Input Setup:

- Directory Setup:** Includes three input fields: "ML_Model", "Input Image Directory", and "Output Directory".
- Input Parameters:** Includes a "Break Image size" field with a note: "(The same as ML_model training inputs)".
- A green "_Run_" button is located below the input parameters.

Output Results:

- Crack Damage:** Includes three output fields: "Crack Region (%)", "Total Crack Length (pixel)", and "Crack Density (in/sqft)".
- Spall Damage:** Includes one output field: "Spall Region (%)".

Callouts:

- Three boxes at the top point to the "ML_Model", "Input Image Directory", and "Output Directory" fields, with labels: "Input the model directory", "Input the image directory", and "Input the output image directory".
- A box on the right points to the "Break Image size" field with the label: "Input the size of image used for the deep learning model calibration".
- A box on the right points to the "Crack Density (in/sqft)" field with the label: "Output:" followed by a list of metrics.

Logos and Footer:

The bottom of the window features logos for PITT | IRISE, University of Pittsburgh, pennsylvania DEPARTMENT OF TRANSPORTATION, ALLEGHENY COUNTY, Michael Baker INTERNATIONAL, GOLDEN TRIANGLE CONSTRUCTION GENERAL CONTRACTORS, and PENNA TURN PIKE. Below the logos is a photograph of a large steel truss bridge under construction.

Delamination Evaluation

The screenshot shows a web application titled "Delamination Evaluation" with a blue background. It features two main sections: "Input Setup" and "Output Results".

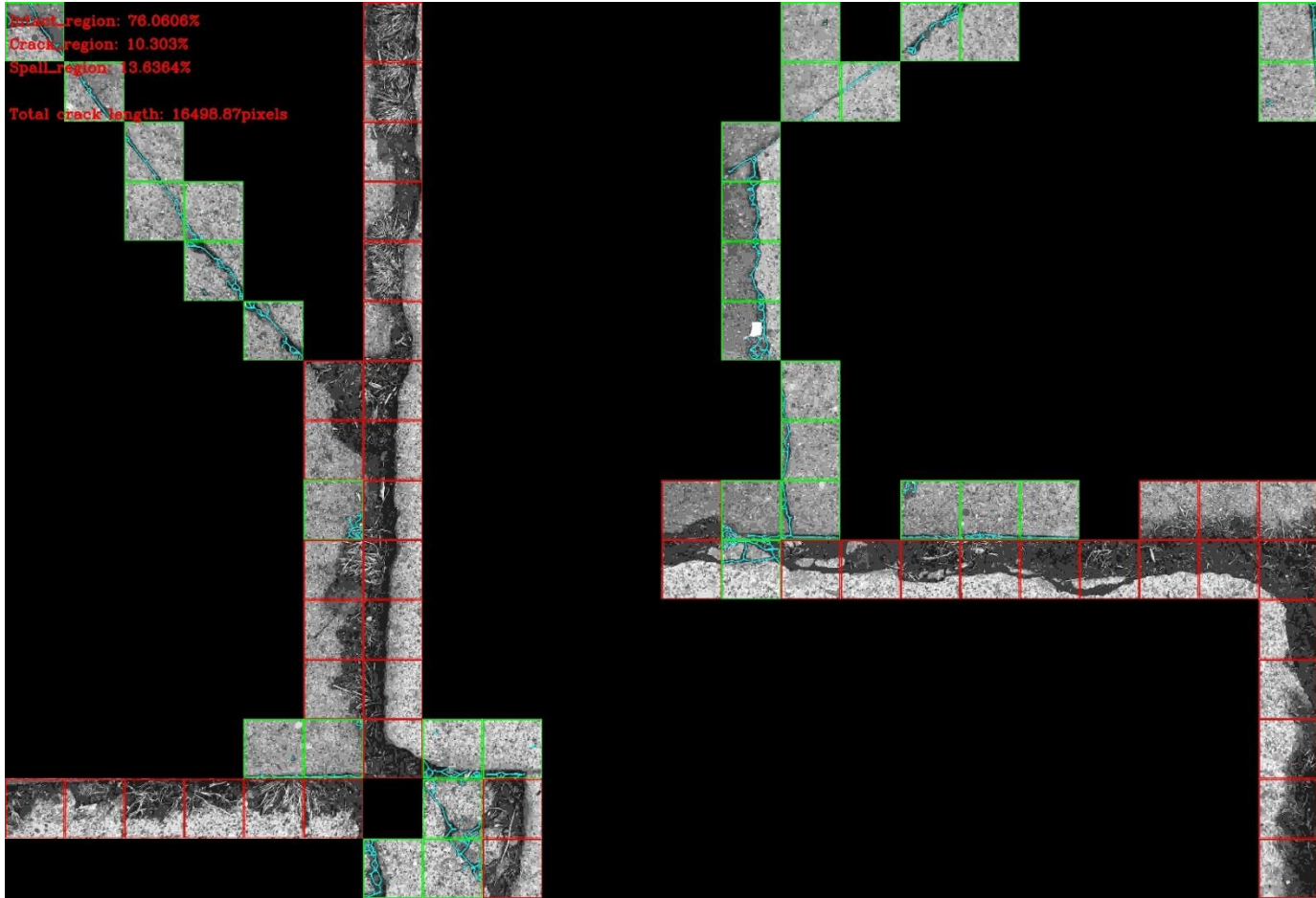
Input Setup: This section contains a "Directory Setup" area with three input fields: "ML_Model", "Input Image Directory", and "Output Directory". Below these is a "Break Image size" input field and a green "Run" button. Callout boxes point to these fields: "Input the model directory" points to "ML_Model", "Input the image directory" points to "Input Image Directory", and "Input the output image directory" points to "Output Directory".

Output Results: This section contains a "Dlamination Density (%):" label followed by an input field. A callout box points to this field with the text "Output: Delamination areas".

Another callout box on the right points to the "Break Image size" field with the text "Input the size of image used for the deep learning model calibration".

At the bottom of the application, there is a white banner with logos for PITT | IRISE, University of Pittsburgh, pennsylvania DEPARTMENT OF TRANSPORTATION, ALLEGHENY COUNTY, Michael Baker INTERNATIONAL, GOLDEN TRIANGLE CONSTRUCTION GENERAL CONTRACTORS, and PENNSYLVANIA TURN PIKE. Below the banner is a night-time photograph of a city skyline with a bridge in the foreground.

Output Example



Spalling Region 

Crack Region 

Crack 