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

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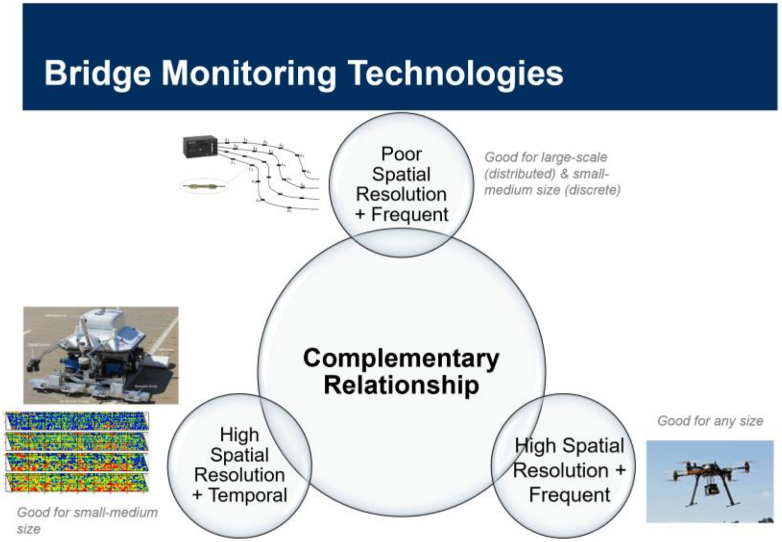
The Research Problem

- ❑ 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

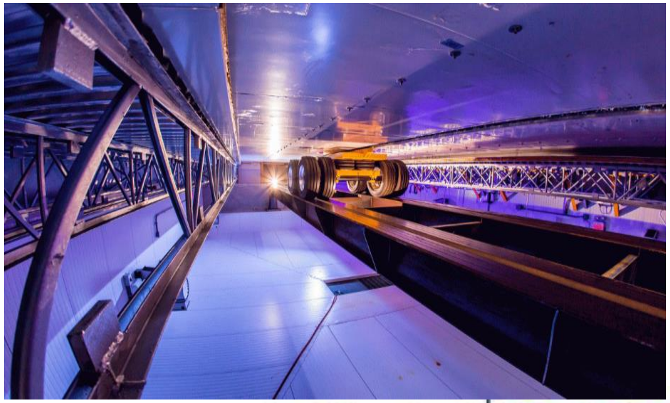


- ❑ A more comprehensive integration framework to integrate the results taken from NDE/SHM/visual inspection is needed

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)

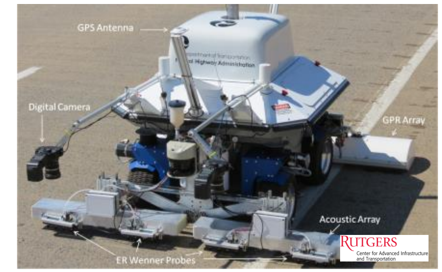


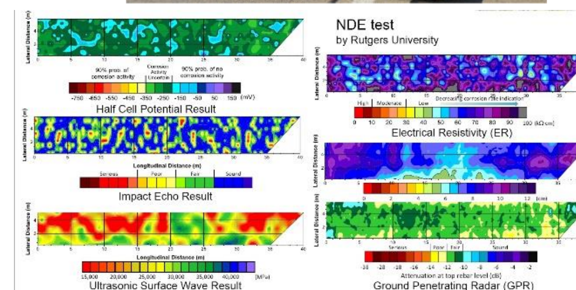
- Identifying the synergies among bridge degradation, remaining service life, and the results taken from the multimodal sensing technologies (SHM, NDE, and UAV-based)

Project Approach/Deliverables

Tasks:

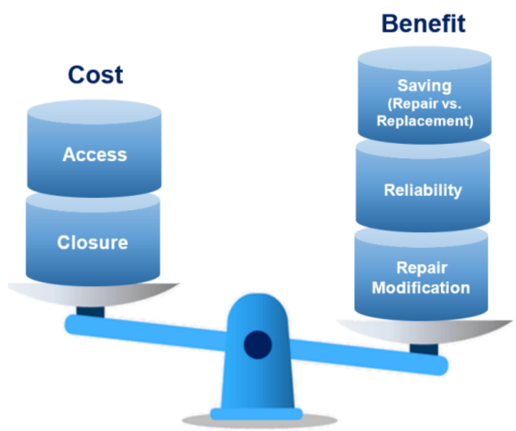
- ❑ Collection of High-Resolution and High-Temporal Data from the BEAST Specimen
- ❑ Processing of Collected Data
- ❑ Advanced Statistical Data Analytics
- ❑ Development of Recommendations

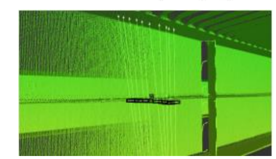


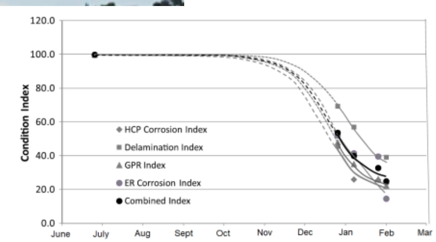


Deliverables:

- ❑ 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.

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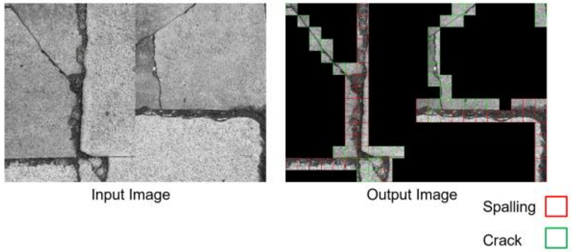
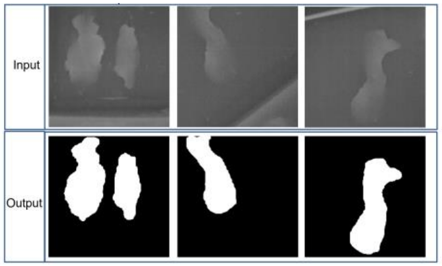
Application of Research Results

- Pitt Bridge Condition Assessment System (PittBCAS): Automated detection and quantification of cracks, spalls and delaminatrion 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	Delam-ination				
Category #3	9	none	none	0.0	none	0	none
Light	8	none	none	0.0 < E.P.< 0.35	none	0 < C.C.<1	none
Deterioration	7	none	< 2%	0.35 < E.P.< 0.45	≤ %5	0 < C.C.<2	none
Category #2 Moderate	6	< 2% spalls or sum of all deteriorated and/or contaminated deck concrete (≥2#/C.Y.Cl) < 20%					
Deterioration	5	< 5% spalls or sum of all deteriorated and/or contaminated deck concrete 20% to 40%					
Category #1 Extensive	4	> 5% spalls or sum of all deteriorated and/or contaminated deck concrete 40% to 60%					
Deterioration	3	> 5% spalls or sum of all deteriorated and/or contaminated deck concrete > 60%					
Structurally	2	Deck structural capacity grossly inadequate					
Inadequate	1	Deck has failed completely – Repairable by replacement only					
Deck	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

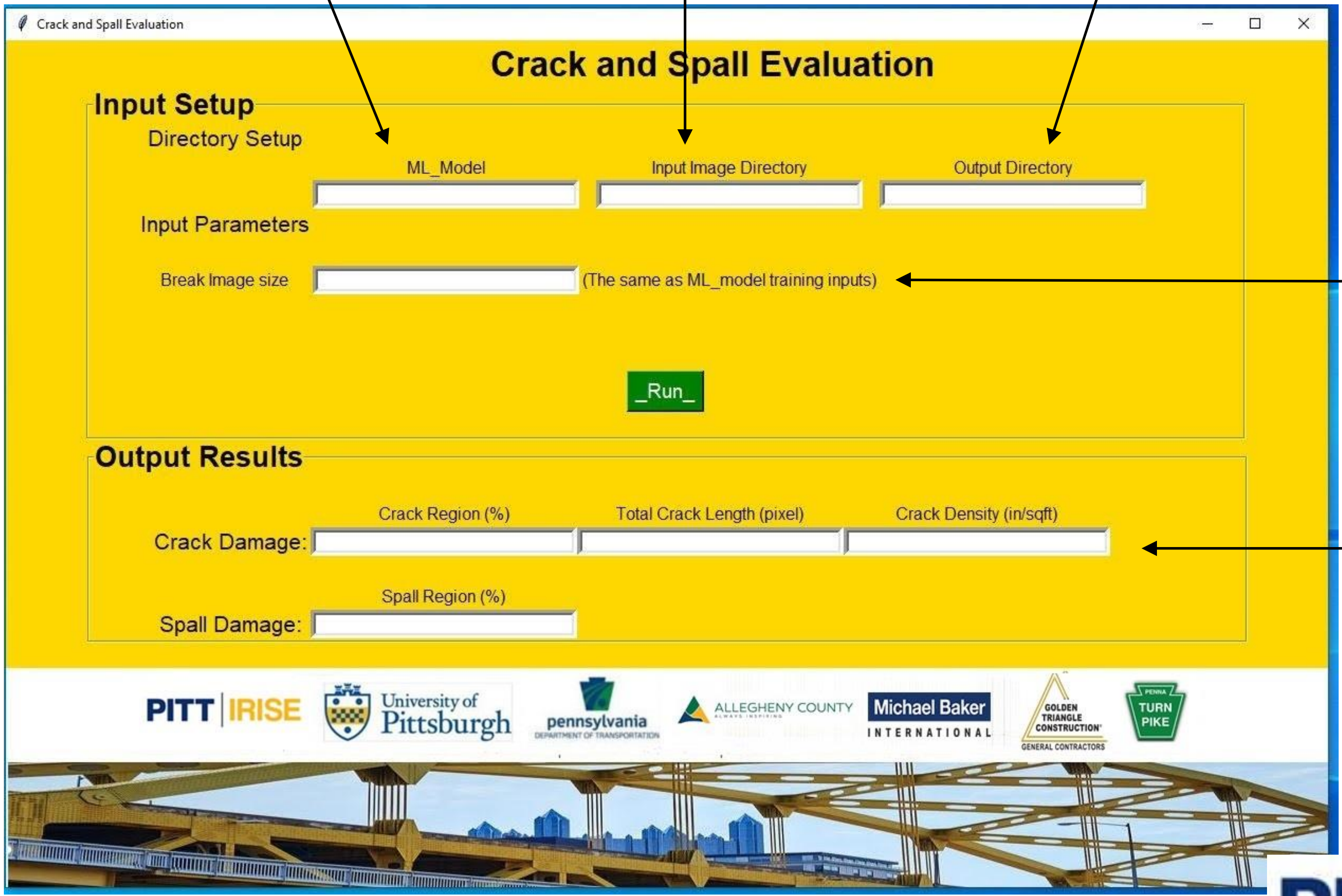
Click to open the interface for Delamination Evaluation

Crack and Spall Evaluation

Input the model directory

Input the image directory

Input the output image directory

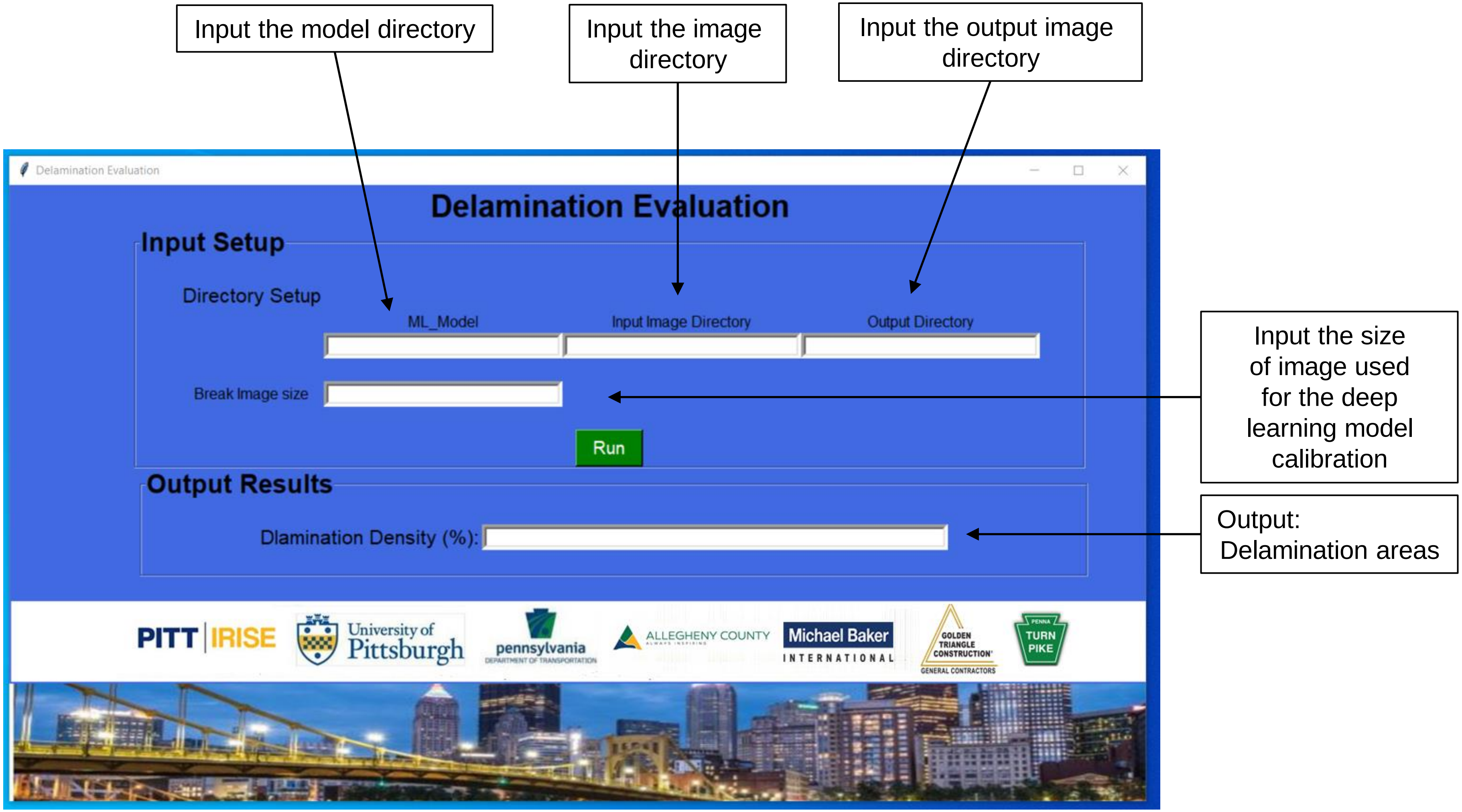


Input the size of image used for the deep learning model calibration

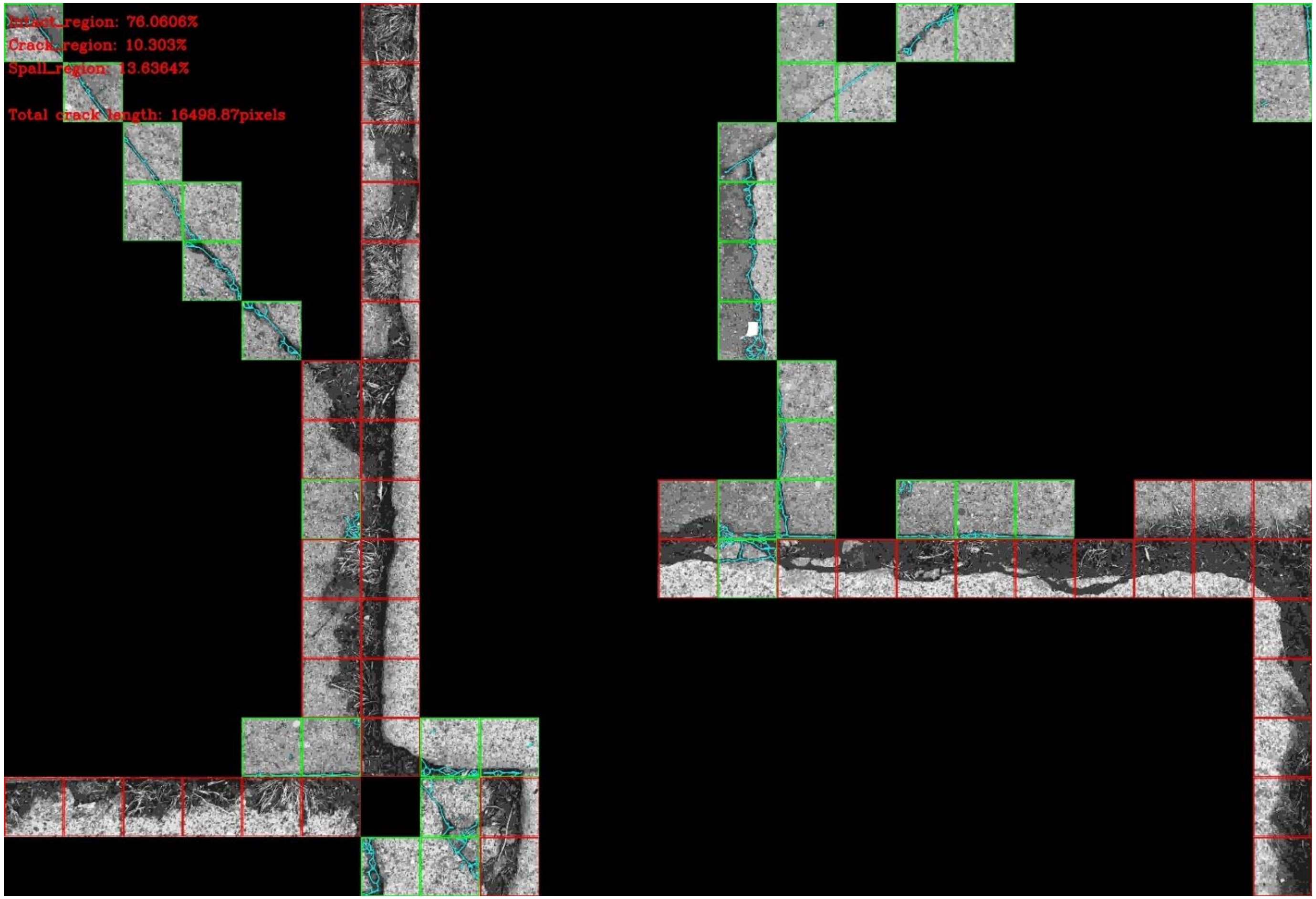
Output:

- Crack region density
- Total crack length
- Crack density
- Spall region density

Delamination Evaluation



Output Example



Spalling Region Crack Region Crack