Corrosion Detection Under Varying Illumination and Wetting Conditions: Applications for Pipelines

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1. Research Problem

a) Most of the existing image-based approaches for corrosion detection are tested on images acquired under uniform illuminations i.e., inherent variations in the ambient lighting conditions are ignored.

b) Varying illuminations, shadows, water wetting, and oil wetting are unavoidable in pipeline applications, it is important to devise a robust technique for corrosion identification.

2. Research Objective

To identify the corrosion in structural steels under varying illuminations, cast shadows, water wetting and oil wetting conditions- using color spaces and neural network.

3. Methodology

a) Four different color spaces namely 'RGB', 'rgb', 'HSV' and 'CIE La*b*' along with a multi-layer perceptron (MLP) is configured and trained for detecting corrosion under real-world illumination scenarios.

b) Training (5000 instances) and validation (2064 instances) datasets for this purpose are generated from the images of corroded steel plates acquired in the laboratory under varying illuminations and shadows, respectively.

c) Each combination of color space and an MLP configuration is individually assessed and the best suitable combination that yields the highest 'Recall' value is determined. An MLP configuration with a single hidden layer consisting of 4 neurons (1st Hidden Layer (HL)(4N)) in conjunction with 'rgb' color space is found to yield the highest 'Accuracy' and 'Recall' (up to 91% and 82% respectively).

d) The efficacy of the trained MLP to detect corrosion is then demonstrated on the test image database consisting of both lab-generated partially corroded steel plate images and field-generated images of a bridge located in Moorhead (Minnesota).

4. Generating Image Datasets

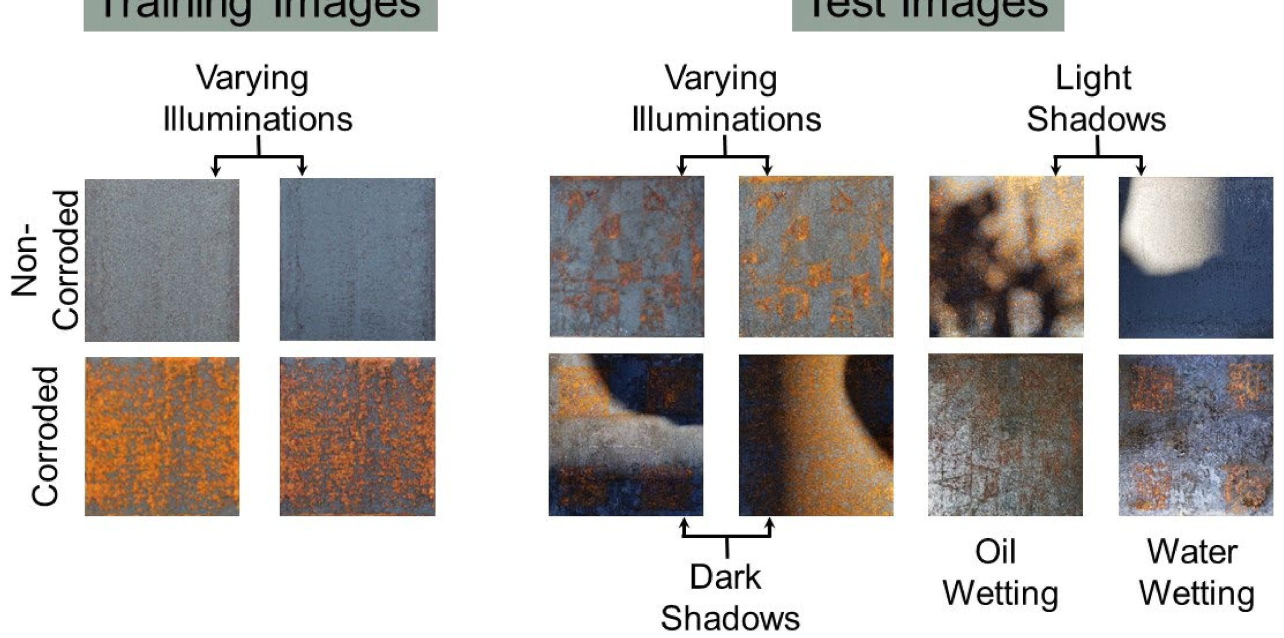


Fig 1: Non-corroded and corroded steel plates used for training purposes and test images acquired at different illuminations, shadows, water wetting, and oil wetting.

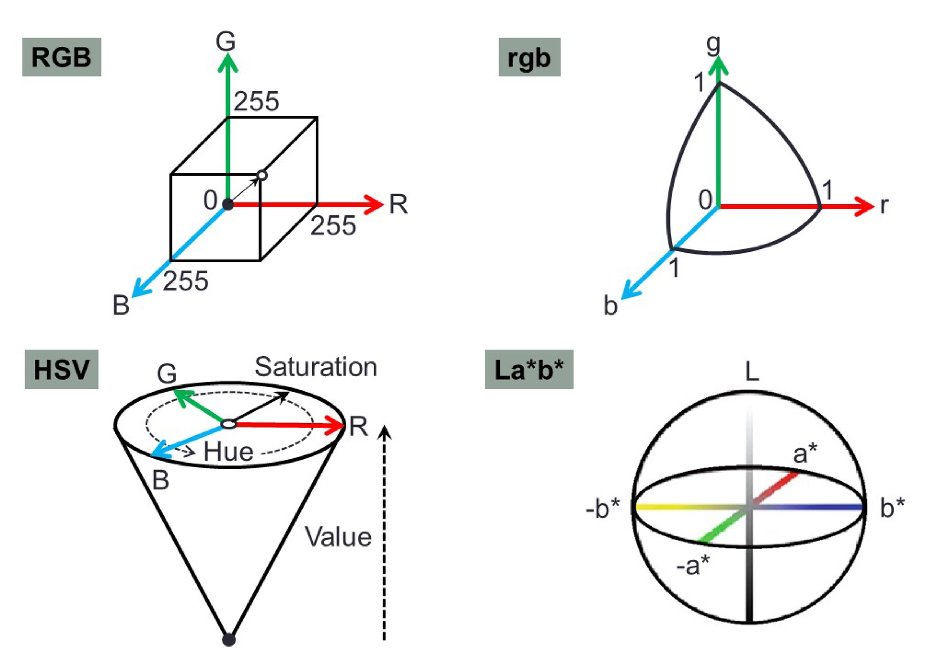


Fig 2: Color spaces in three-dimensional coordinate systems: (a) 'RGB', (b) 'rgb', (c) 'HSV' and (d) 'CIE La*b*'.

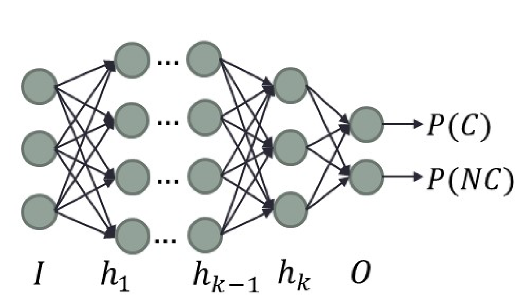


Fig 3: Schematic of feed-forward NN.

Configuration	Hidden Layers	Neurons
ANN 1	1	2
ANN 2	1	4
ANN 3	2	2-2
ANN 4	3	50-10-4

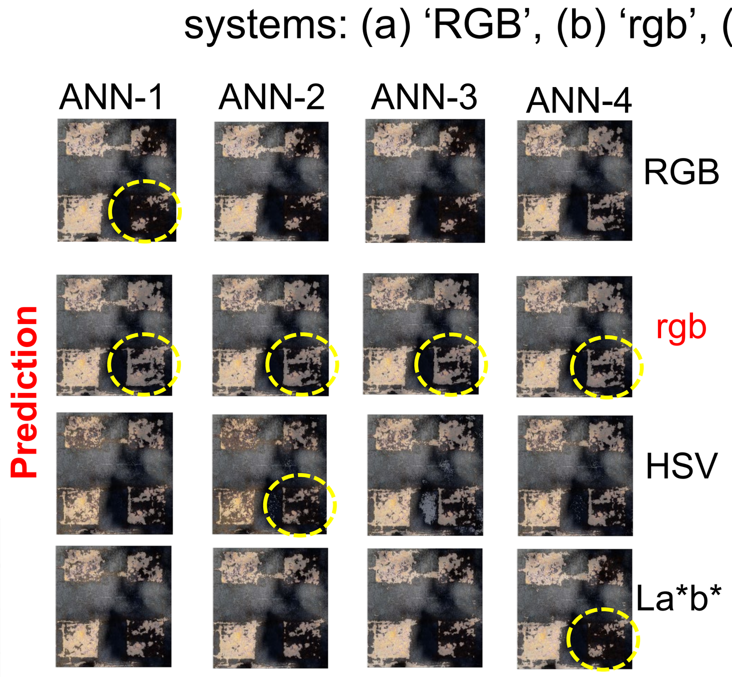


Fig 4: Performance of various ANNs and color spaces.

✓ Among all the color spaces "rgb" performed well and its performance is not sensitive to the number of neurons and layers in the ANN.

5. Clustering and Validation

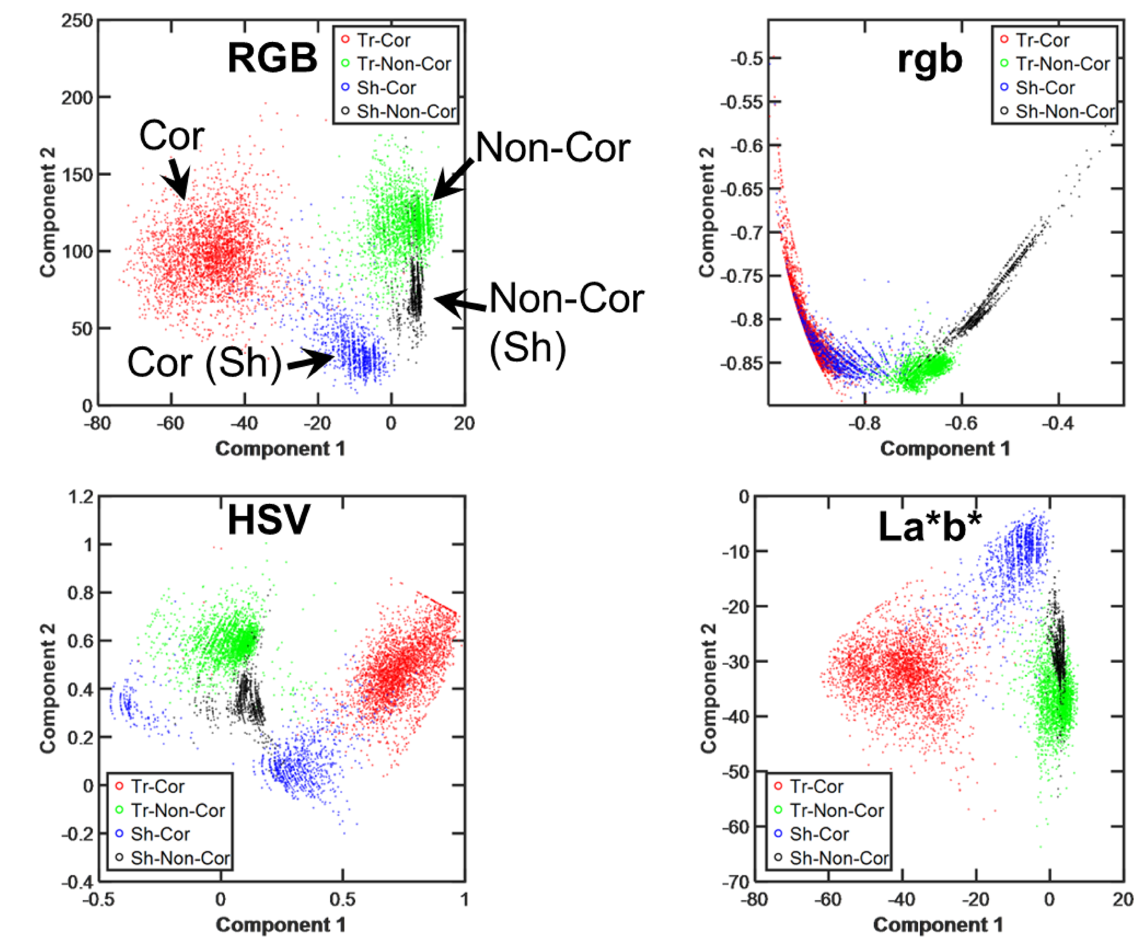


Fig 5: Among the considered color spaces, the top two principal components of "rgb" led to clear and distinguishable clusters indicating superior performance.

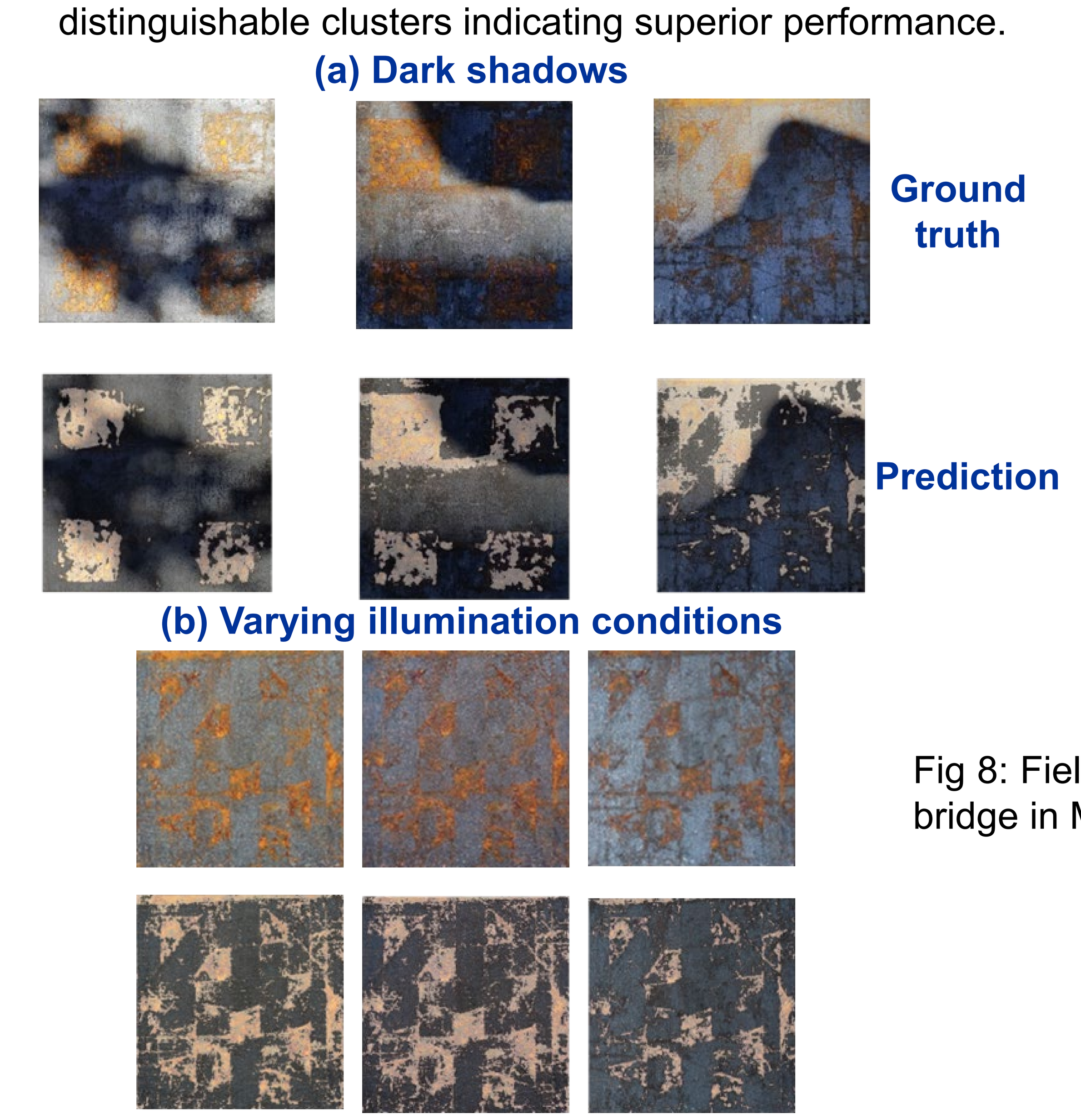


Fig 7: In-lab validation of the trained ANN to identify corrosion under (a) dark shadows and (b) illuminations.

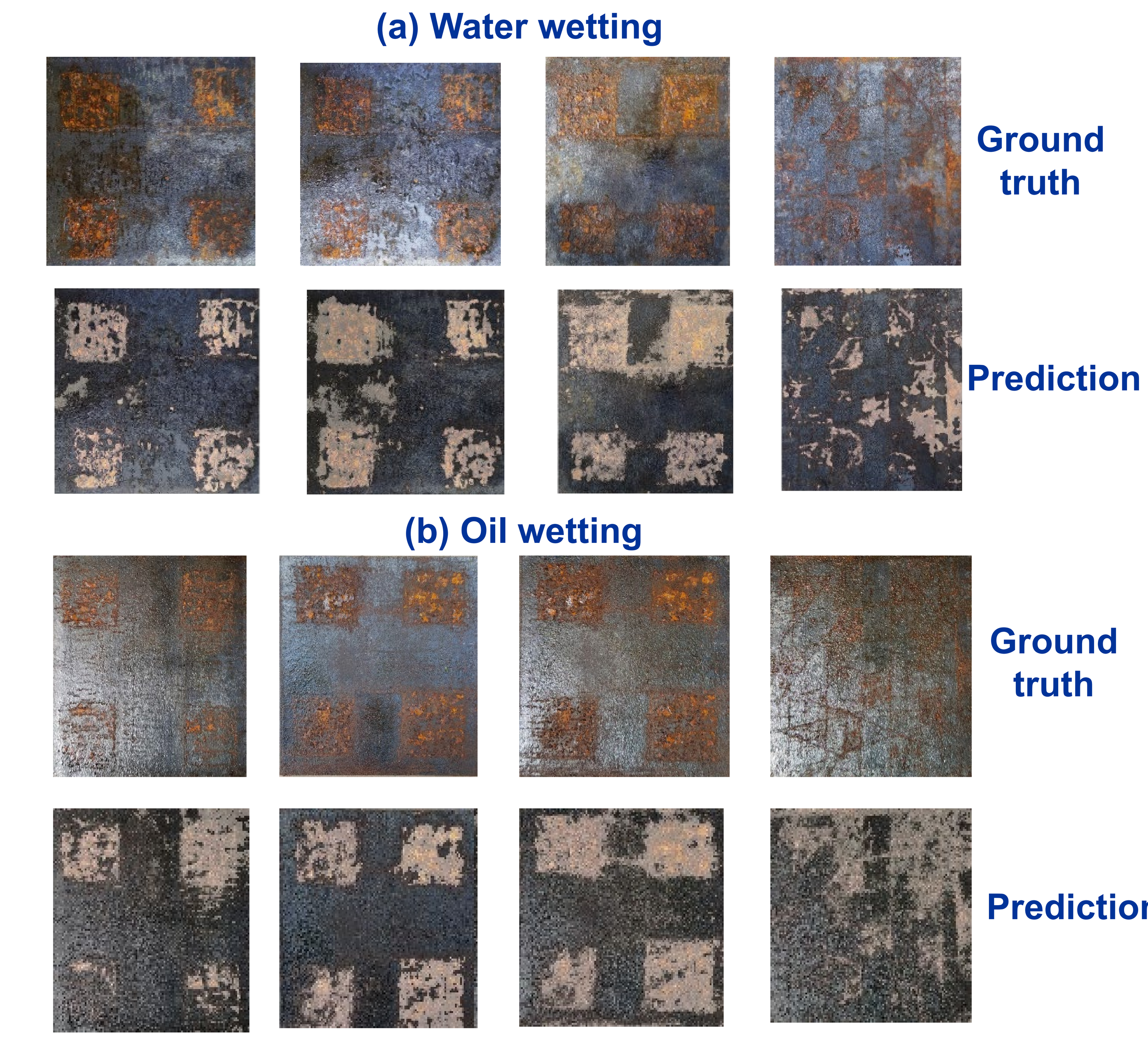


Fig 6: In-lab validation of the trained ANN to identify corrosion under (a) water and (b) oil wetting.

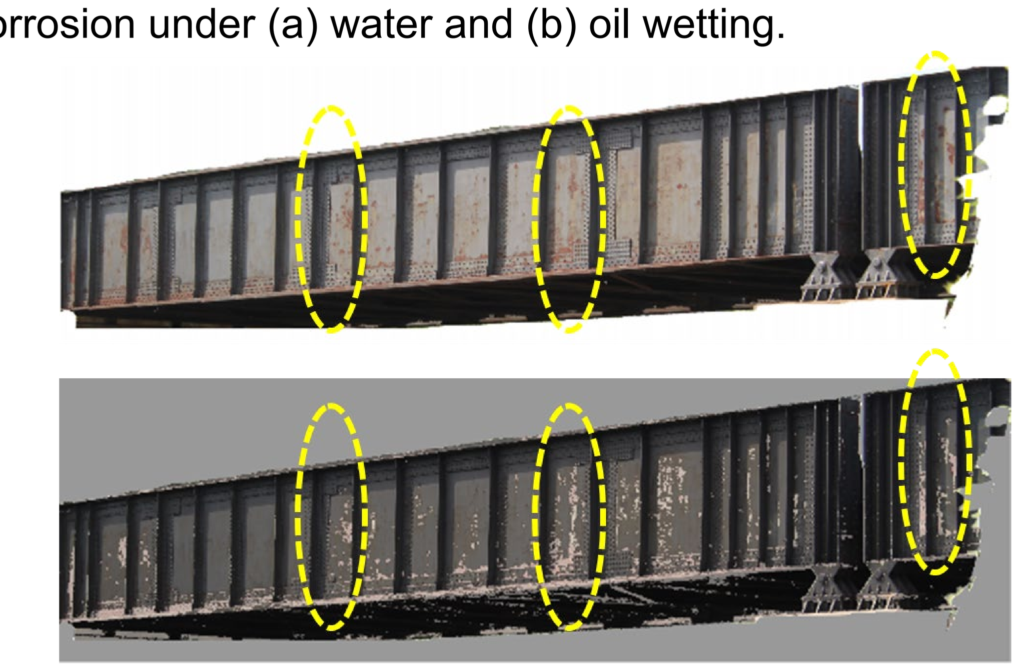
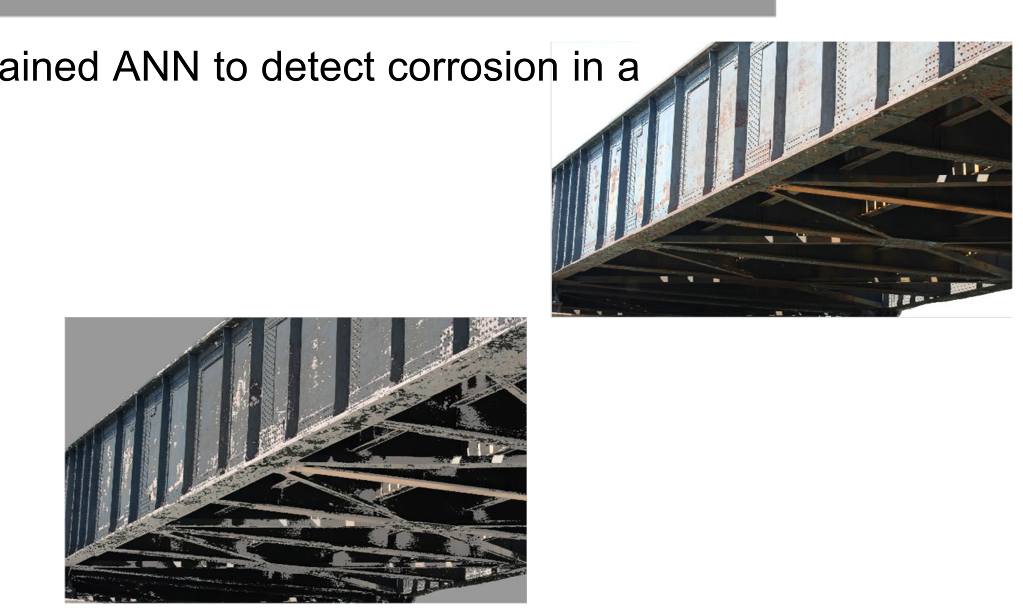


Fig 8: Field validation of trained ANN to detect corrosion in a bridge in Moorhead, MN.



6. Acknowledgments

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7. References

1. Lavadiya, D. N., Sajid, H. U., **Yellavajjala, R. K.**, & Sun, X. (2022). Hyperspectral imaging for the elimination of visual ambiguity in corrosion detection and identification of corrosion sources. Structural Health Monitoring, 21(4), 1678-1693.

8. Public Project Page

https://labs.engineering.asu.edu/dams/