Hyperspectral Image Analysis for Mechanical and Chemical Properties of Concrete and Steel Surfaces

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INTRODUCTION

According to the 2017 ASCE Report Card, 39% and 15% of 614,387 bridges in the U.S. are more than 50 years and 40 to 49 years, respectively. The number of deficient bridges is increasing. One of the most common causes of reinforced concrete deterioration is corrosion of steel reinforcing bars. Currently, most bridges are visually inspected every two years using boom/ snooper trucks to get access to various areas to be inspected. The subjective visual inspection often leads to inconsistent results that are less useful in bridge management. Hyperspectral camera, installed on an unmanned aerial vehicle, can potentially supplement visual inspection with quantifiable and reliable imagery from remote and safe operations. It can be used to identify physical characteristics (e.g., concrete cracks) and characterize chemical features (e.g., steel corrosion).

METHODS

Hyperspectral imaging is based on light reflectance from an exposed surface (long and narrow like a ‘line’) of concrete or steel members. As a hyperspectral camera moves in a direction perpendicular to the ‘line’, the entire surface of a structural member can be scanned. For each pixel in the scanned area, spectral analysis is made to understand the mechanical and chemical features on the scanned surface, which can be used to evaluate/predict the condition of the tested member (e.g., reinforced concrete) according to the following flowchart:

Camera setup at optimal measurement distance

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Imaging as camera moves at constant speed

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Hyperspectral image processing with reflectance calibration

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Machine learning for interesting feature extraction

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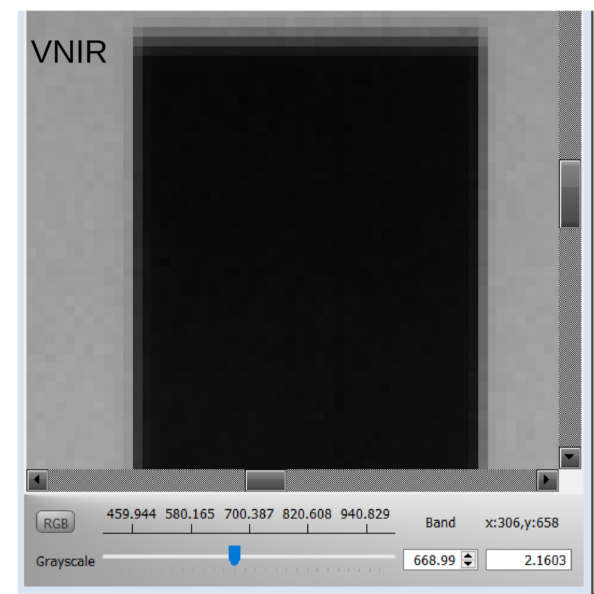
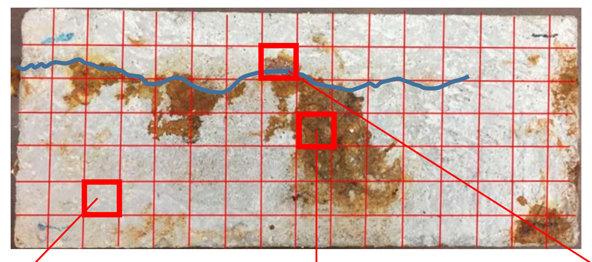
Classification of structural condition from reference imagery

RESULTS

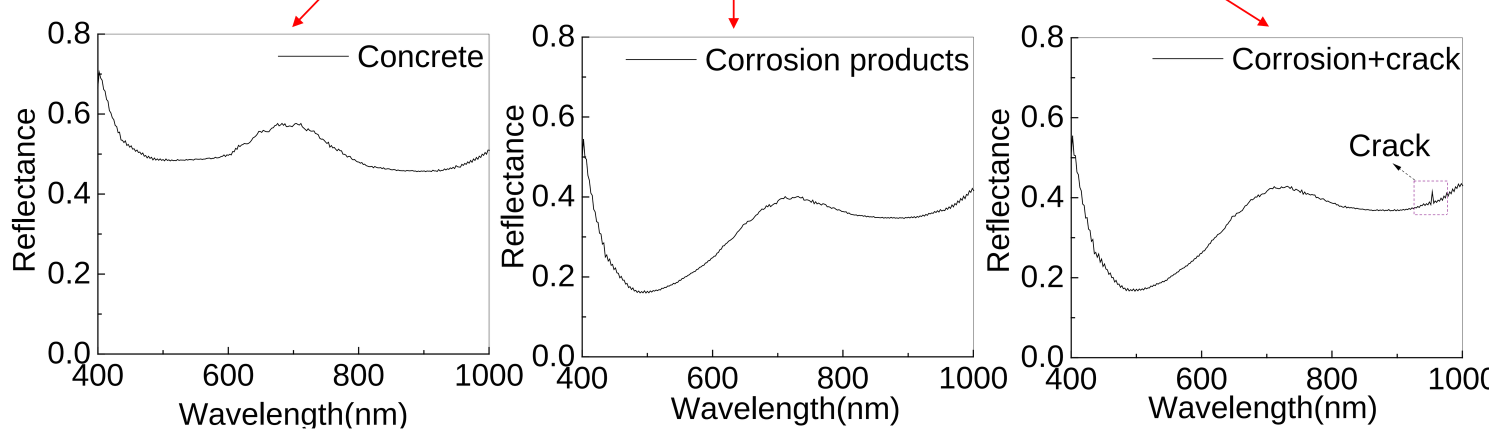
A co-aligned dual VNIR-SWIR hyperspectral camera will be used in this study. When focused at 4 ft distance, the camera produces imagery with resolution of 1~2 transition pixel from VNIR (400-1000 nm) and 1~3 pixel from SWIR (900-2500 nm) from a measurement distance of 4~6 ft away from an object.



A reinforced concrete (RC) slab specimen was submerged in 3.5 wt.% NaCl solution and developed a longitudinal crack along a steel bar over time. The reflectance spectra in representative pixels with various features (concrete, corrosion products, and crack) are different in magnitude and wavelength.



RC specimen with corrosion-induced longitudinal crack



Reflectance spectra for representative pixels

Reflectance at specific wavelength

Reflectance / Wavelength	Concrete	Corrosion Products
510 nm	0.48	0.16
890 nm	0.46	0.35

CONCLUDING REMARKS

- Hyperspectral imagery includes both spatial and spectral information on a structural surface scanned with spatial resolution at pixel level.
- The reflectance spectrum at each pixel of the scanned area can potentially be used to characterize physical defects or chemical features indicative of the deterioration process of bridges.
- Classification models can be developed to evaluate/predict the condition of existing bridges, providing critical information for bridge management.

FUTURE PLAN

- The desirable pixel size can be determined by adjusting the measurement distance, exposure time, and frame period.
- The defect detection precision and sensitivity will be evaluated using standard samples with known composition and grain sizes.
- Steel reinforcing bars are embedded into concrete slab specimens, and impressed with electrical current to attain various levels of corrosion. The reflectance spectra will be obtained during the entire accelerated corrosion tests and related to the degree of steel corrosion (chemical changes on specimen surfaces).
- Principle spatial and spectral features of the obtained images will be extracted. The data will be divided into a bigger training set and a smaller validation set. Hyperspectral imaging classification models will be developed based on the training set and verified by the validation data set.

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