Contract No:

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Disclaimer:

LDRD-2021-00401
LDRD External Report Summary

Title of Project
Corrosion Detection of Material Surfaces Using a Java-Based Software

Project Start and End Dates
Project Start Date: Nov 2020
Project End Date: End June 2021

Project Highlight
The main milestone of performing a proof of principal test was reached, by getting access to the data and extracting out significant features of a crack defect using the Java-based software, Fiji™ (ImageJ). The data was also used to programmatically identify the width of cracks by using Gaussian fits.

Project Team
Principal Investigator: Holly B. Flynn
Team Members: Raymond G. Belliveau; Michael Martinez-Rodriquez
External Collaborators (all external collaborators and their respective organizations that participated in this project: N/A

Abstract
Automation techniques for recognizing material defects are very common in fields like infrastructure survey and civil engineering; however, the defects are usually easily distinguishable from their background, on a larger scale (e.g. cement bridges), and very specific. Extracting information about a defect that is near or equal to the background of the data can be extremely difficult. Images with heavy background corrosion, pitting, cracking, and man-made defects (such as welding) makes extracting information on a specific defect near-impossible. This is especially true when the defect is on the micron level and the dynamic range of your image taking instrument is low. So, a simplified, Java-based Fiji™ (ImageJ) defect detection program, dependent on a 'flag' system, was proposed for data that has a micron level hairline crack that is near or equal to the background. The utilization of the built-in functions, plugins, and macro scripting capability of the Java-based software sends a series of flags to the user that help to identify if the surface contains a defect of interest and to characterize that defect.

Objectives

- The main milestone was to perform a proof of principal test. This is demonstrated by:
  - Extracting data (images) from the measurement instrument.
  - Processing the images through the Java-based software and identifying the defect of choice (crack).
  - Using the information from the Java-based software, Fiji™ (ImageJ), to process through Gaussian fitting routines and other processing techniques.

REVIEWS AND APPROVALS

1. Authors:

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Name and Signature Date

2. Technical Review:

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Name and Signature Date

3. PI's Manager Signature:

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Name and Signature Date

4. Intellectual Property Review:

This report has been reviewed by SRNL Legal Counsel for intellectual property considerations and is approved to be publicly published in its current form.

SRNL Legal Signature

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Name and Signature

Introduction

Automation techniques for recognizing material defects are very common in fields like infrastructure survey and civil engineering; however, the defects are typically easily distinguishable from the background surface, occur on large structures, and due to the size of the defect can be imaged with a camera. In many of these cases the analysis approach is either computationally heavy such as a neural network or the feature extraction is overly complicated and very specific. It is proposed that a simple flag-based system using a macro program written in a Java-based software can identify the location of a crack and extract the relevant feature information for analysis and machine learning.

Cylindrical stainless-steel containers for radiological materials at the Savannah River Site become compromised over time due to extensive radiation exposure. The containers consist of a cylindrical body and welded lid, and in preparation for study are cut into sections. Individual sections are imaged using a laser confocal microscope (LCM). Due to the curvature of the container the LCM is used to 'flatten' the images for analysis and defect detection. The areas of interest are also nearest the lid weld location, which has been indicated as the region most likely to develop cracks. The cracks are typically only a few microns wide. Due to the small size of the cracks and the curvature of the containers, the LCM is a great instrument for extracting data; however, the LCM takes a very long time to image the samples and often produces sample images with low dynamic range. In combination with the problems due to the welding defects, corrosion, and pitting that has also occurred during the radiation and heat exposure, the crack is often difficult to differentiate from the rest of the sample surface.

A simplified, Java-based Fiji™ (ImageJ) defect detection program, dependent on a 'flag' system was proposed. The utilization of the built-in functions, plugins, and macro scripting capability of the Java-based software (ImageJ) sends a series of flags to the user that help to identify if the surface contains a defect of interest. Further analysis and examination of the region can be had through x, y location estimation and Gaussian fits. This contributes a less-computationally heavy way of extracting out features from an image that can be used as is or can be further used in supervised learning.

Approach

The image analysis process is based on identifying flags that tell the user and the program that a defect has potentially been identified. The more flags that are weighted the higher the probability that a defect has been found amongst the background noise. The flags are based on key facts about what a specific defect is. For the purpose of this study, the defect of interest is a crack, defined as an object that ideally has the lowest intensity in its local area, has a high directionality, can be reduced to a single thread or skeleton, and has a distinguishable Gaussian-shaped profile.

Accomplishments

- An in-house written stitching routine was built to extract the data from the VK4 files that the laser confocal microscope generates. This stitching routine is demonstrated by three steps in Figure 1
- A flag-based system was proposed and performed on the images. This approach is a simpler, less computationally intense approach to defect detection especially in low-dynamic range, noisy images.
- Figure 2 are images of two separate cracks with varying levels of background noise. The x, y locations determined by the flag-based system are drawn on each image as small squares. The images show that the estimated x, y locations determined to be the crack center by the flag-based system is a very good estimate.

- The determined x, y values were then used to fit Gaussian routines to the estimated crack locations. Figure 3 shows two histograms that plot the frequency that each FWHM is measured. A red line is drawn to indicate prior analysis determination of crack width.
- **The short project successfully completed the proof of concept.**

Future Directions

- The defect detection program written extracts out features of a defect, such as a crack. These features can be utilized in supervised machine learning, using pre-labelled data. A potential PDRD is in review that will be utilizing this feature extraction capability on pre-labelled welds.
- The short project proof of concept was successful, but with more time the feature extraction software can be automated and improved upon. There is a possibility for continuation under the 3013 project scope to further improve and automate the routine for defects found in these structures.

FY 2021 Peer-reviewed/Non-peer reviewed Publications

Peer-Reviewed Publication (Written; Under review by co-authors; Internal Review and Submission Imminent)

Intellectual Property

N/A

Total Number of Post-Doctoral Researchers

2; Holly B. Flynn, Onsite; Raymond G. Belliveau, Onsite.

Total Number of Student Researchers

N/A

Include all images, charts and figures with captions, as shown below.

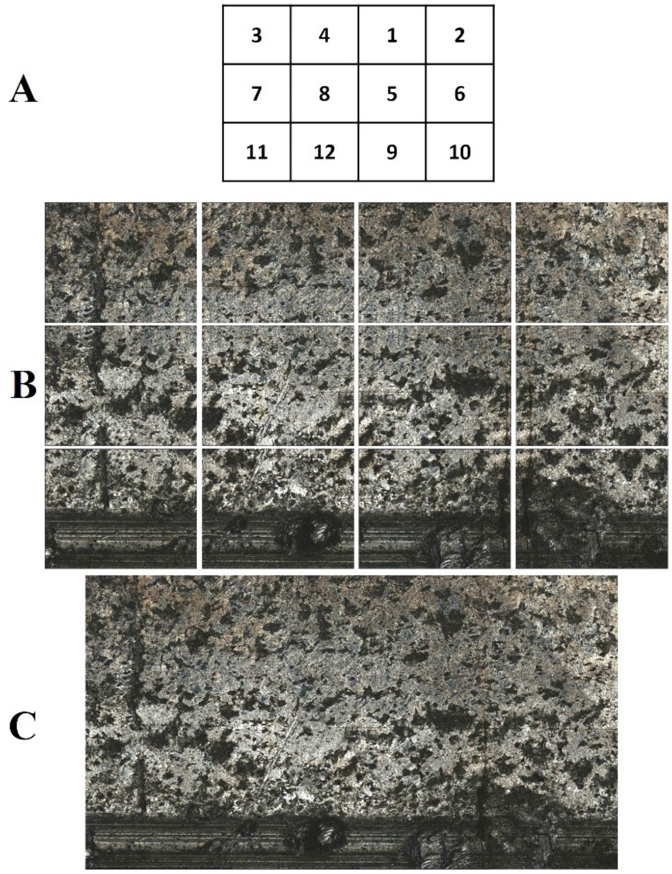

Figure 1: A: Map of the relative locations of each image based on the filename convention. B: Twelve optical-intensity images that cover a region of interest. Each image overlaps partially with the adjacent images. C: Result of the stitching routine on the twelve images in B.

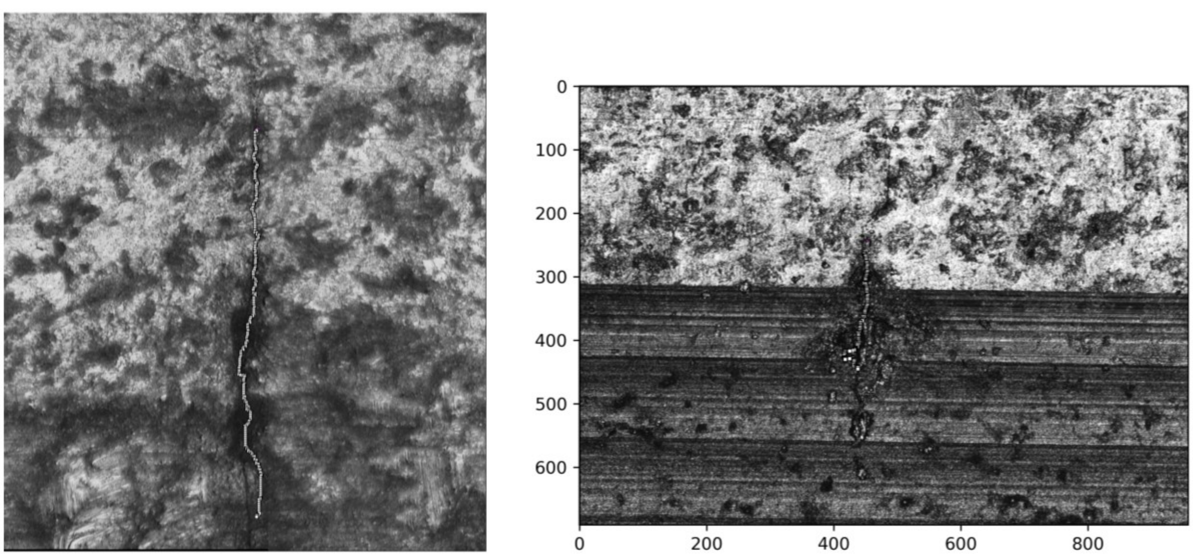

Figure 2: *(Left)* Estimated x, y position of the crack determined by the flag-based software for an image with corrosion and pitting present. *(Right)* Estimated x, y position of the crack determined by the flag-based software for an image with welding defects present (darker region at bottom).

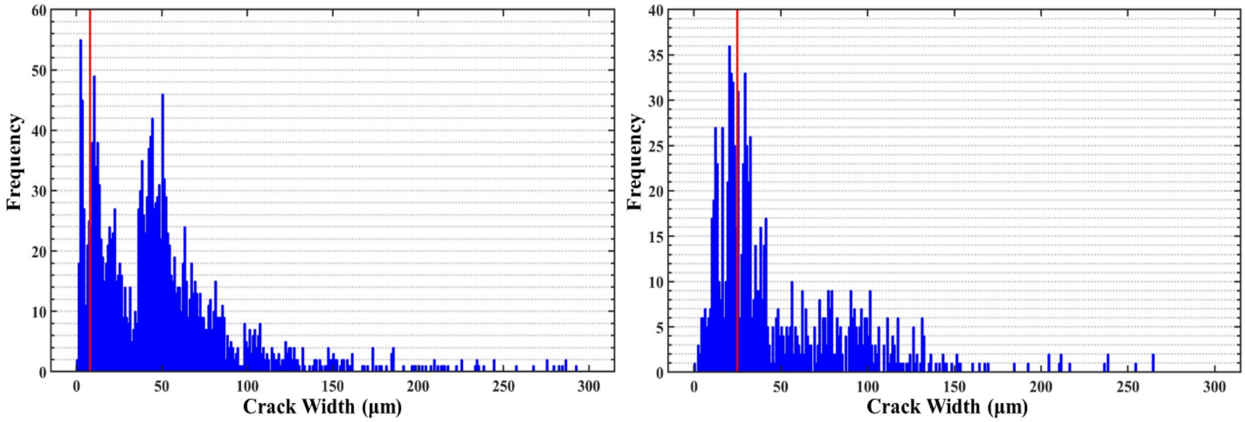

Figure 3: Histograms of the FWHM values calculated using Gaussian fits and the estimated x, y crack location determined by the flag-based system. The red line is the size of the crack determined by a prior analysis. Each Histogram relates to the images in Figure 2, respectively. The dual peaks in the left hand image is due to the heavy corrosion regions that the crack passes through, whereas, the image with weld defects has less corrosion.