Image Enhancement Based on Software Filter Optimization for Corrosion Inspection

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Abstract—This project is focusing on corrosion inspection using image. Inspection which have particularly challenging environmental conditions and characteristics, increase the complexity of the inspection operation. By using software image filter to enhance the image data, it is believe that the object recognition technique will be able to analyze the image data accurately. A few software filters have been identified in this works. Therefore, in order to obtain suitable software image filter, neural network is use for optimization. The simulations result shows corrosion defect image can be enhanced using combination of features based image enhancement filters, with regards the corrosion data is able to acquire for recognition process.

Keywords-component; Image Enhancement; Neural Network; Corrosion

I. INTRODUCTION

Corrosion image usually pollute by environment noise and illumination problem, during the inspection or acquisition process. In image inspection process, the quality of image would effect the result. Removing the noise before data acquisition of the image, would improve the accuracy of the inspection result.

This research is focusing on the pipeline corrosion as defect on the pipeline causing major loss to industry [1]. Figure 1 shows sample of corrosion defect on pipeline surface that will be used in this research for simulating the image enhancement optimization.

II. VISUAL INSPECTION

One of the main applications of vision system is use in inspection system. By using vision system in inspection system, the accuracy and reliability of quality can be fix on within the predetermine range. Visual inspection systems are used to check parts for dimensional accuracy and geometrical integrity. Despite the fact that human able to perform image inspection using their pair of eyes, the detail repetition of some inspection tasks is simply beyond the capability of humans.

Remote Visual Inspection or RVI is one method of non-destructive testing (NDT) use in corrosion inspection [2]. RVI is a visual examination method that aids in acquisition of visual data by using visual equipment but not limited to video pan/tilt/zoom cameras, borescopes, push cameras, or robotic crawlers. It is frequently used where distance, angle of view and limited lighting may impair direct visual examination or where access is limited by time, financial constraints or atmospheric hazards. However the term “remote” is defined as being operated by pilot or operator during the inspection, thus limit the capabilities of automated inspection system.

In visual inspection system, the quality of the image plays a great role in determining the accuracy of the data. Even though the cameras were useful for observing gross visual features, yet for detailed visual inspection, it is not very suitable. Therefore, image enhancements are encouraged to be done on early stage of the system after the image acquisition process was done [3]. The enhance image would likely produce accurate image data that improve the result of inspection as the visual inspection rely on the quality of the image and data acquisition before processing it.

III. IMAGE ENHANCEMENT

A. Image Enhancement Filter

The image enhancement filters use in this study emphasizes on image features that are the characteristic of surface defects created due to corrosion. Several filters were identified based on previous researches [4][5] that were used to enhance image for surface corrosion features [6][7][8].
Table 1 listed the image enhancement filter based on “How they do it?”, and “What do they enhance?".

Linear filter is based on the same two techniques as conventional Digital Signal Processing, DSP: convolution and Fourier analysis. It can improve images in many ways: sharpening the edges of objects, reducing random noise, correcting for unequal illumination, de-convolution to correct for blur and motion, etc. [9]. Second is Gaussian filter, a filter whose impulse response is a Gaussian function. Gaussian filters are designed to give no overshoot to a step function input while minimizing the rise and fall time [10]. While, Wavelet De-noising focus on reducing high frequency noise. It direct wavelet transform is computed from the original image, estimate noise level at each wavelet scale separately. This defines a threshold for zeroing wavelet coefficients [11].

<table>
<thead>
<tr>
<th>Homomorphic</th>
<th>Bayer</th>
<th>Wavelet De-noising</th>
<th>Gaussian</th>
<th>Linear</th>
<th>Anisotropic Diffusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>image enhancement and correction</td>
<td>filter mosaic, colour filter array (CFA)</td>
<td>reduces high frequency noise</td>
<td>give no overshoot to a step function input while minimizing the rise and fall time</td>
<td>improve images in many ways: sharpening edges, reducing random noise, correcting unequal illumination, etc.</td>
<td>reducing image noise without removing significant parts of the image content</td>
</tr>
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</table>

Next, Bayer filter mosaic is a color filter array (CFA) for arranging RGB color filters on a square grid of photo sensors [12]. As for Homomorphic filter, it is a generalized technique for image enhancement and correction. It simultaneously normalizes the brightness across an image and increases contrast [13]. Finally, Anisotropic Diffusion enhances image by reducing image noise without removing significant parts of the image content, typically edges, lines or other details that are important for the interpretation of the image. Anisotropic diffusion is a generalization of diffusion process: it produces a family of parameterized images, but each resulting image is a combination between the original image and a filter that depends on the local content of the original image [14].

**B. Image Error Measurement**

Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) are the two error metrics used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower value of MSE shows that the image error is low [15].

The PSNR block computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is often used as a quality measurement between the original and a compressed image. The higher the PSNR value, the better the quality of the compressed or reconstructed image [15].

To compute the PSNR, the block first calculates the mean-squared error using the following equation:

\[
MSE = \frac{\sum_{m,n} [I_1(m,n) - I_2(m,n)]^2}{M \times N}
\]  

In the equation (1), M and N are the number of rows and columns in the input images, respectively. Then the block computes the PSNR using the following equation:

\[
PSNR = 10 \log_{10} \left( \frac{R^2}{MSE} \right)
\]  

In the equation (2), R is the maximum fluctuation in the input image data type. For example, if the input image has a double-precision floating-point data type, then R is 1. If it has an 8-bit unsigned integer data type, R is 255.

**C. Optimization - Neural Network**

In this research, artificial neural network is used for optimizing the image enhancement filter algorithm. As network representation provides such powerful visual and conceptual aid for portraying the relationship between the
components or tools of systems that it is used in virtually every field of scientific, social, and economic endeavor [16].

In artificial neural network, the elements called as neurons or node, process the information. The signals are transmitted by means of connection links, and these links possess an associated weight which is multiplied along with the incoming signal (input) for any typical neural network. Finally the output signal is obtained by applying activations to the network input [17].

IV. SIMULATION TEST

The experiment of image enhancement optimization for corrosion defect was simulated on a program developed using MATLAB®. The sample image used in the experiment is RGB image and the size was converted to become square image for easiness of filter installation on the image. Figure 3 shows the flowchart of image enhancement optimization on corrosion defect process. The process are divided into 3 sections; image preparation, software filter installation, and neural network optimization.

In image preparation part, the type and size of image are determined. Next, to avoid burden on the system, the filters were install one by one in the filter installation. On each filtered image, the value of PSNR and MSE were calculated. The max value of PSNR is used for neural network optimization. Due to the weight for each filter is set on value ‘1’, the filtered image with highest PSNR is selected as input image for next layer. The processes only stop when the value of PSNR on the respective layer is lower than value of PSNR on previous layer.
V. Result

To test the image enhancement filter algorithm, the image enhancement process was planned to be simulated until layer iteration 10. However, simulation of the enhancement process stopped after completed layer iteration 6. This is mainly due to the quality of the image has become too bad that caused further filtering process is not able to be performed.

Figure 4 shows the raw image that was installed, together with the 6 images of the enhancement filter. These filters were installed step by step to reduce the burden on the system.

Meanwhile Figure 5 shows the layer iteration 6 for each image enhancement filters. The result of PSNR and RMSE of each filter on each layer can be viewed in Table 2. The red block inside the table show the max value of PSNR on each layer. Figure 6 and Figure 7 show the graph of RMSE and PSNR of image enhancement filter on corrosion image.

### Table 2. Result of Image Filter Optimization on Corrosion Image for N - Iterations; N = 6

<table>
<thead>
<tr>
<th>Filter</th>
<th>Iterations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Linear</td>
<td>57.4346</td>
</tr>
<tr>
<td>Gauss</td>
<td>58.1579</td>
</tr>
<tr>
<td>Wavelet DN</td>
<td>58.2947</td>
</tr>
<tr>
<td>Bayer</td>
<td>57.8967</td>
</tr>
<tr>
<td>Homomorphic</td>
<td>57.1954</td>
</tr>
<tr>
<td>Anisotropic</td>
<td>56.6311</td>
</tr>
</tbody>
</table>

- **Max PSNR**: 58.2947
- **Min PSNR**: 56.556
- **Max RMSE**: 0.3790
- **Min RMSE**: 0.2750

Figure 4. Iteration 1 - Image Enhancement Optimization for corrosion defect

Figure 5. Iteration 6 - Image Enhancement Optimization for corrosion defect
VI. DISCUSSION

From the result explained in previous section, even though the highest PSNR value is already obtained on layer iteration 3 (refer Table 2 as the highest PSNR value among the filters at layer iteration 4 is lower than the highest PSNR value of previous layer; layer 3), the filtration process is still able to continue. But if the program continues to enhance the image after iteration 3, the PSNR value is having tendency to become bigger back compared to the previous layer iteration, as shown in the result of the highest PSNR value of layer iteration 6. Furthermore, the image quality is worsened and at one stage, the filtering process will stop due to the error on the image properties. An example of image (with low quality) is shown in Figure 8 which is obtained at iteration 6.

From Table 2, the highest PSNR values compared to others layer is in layer iteration 3. Figure 9 (a) shows the raw image, which is used as initial image. The image is enhanced using optimized enhancement filter until layer iteration 3, and the resulting image is shown in Figure 9 (b). The quality of the image and the quality of the corrosion features, improved compare to the original image. The combination of image enhancement filter uses for this image is (1) wavelet De-noising; (2) Linear filter; (3) wavelet De-noising.

Figure 6. Graph of RMSE for image filter on corrosion image

Figure 7. Graph of PSNR for image filter on corrosion image

Figure 8. Optimized image - Iteration 6
VII. CONCLUSION

This paper describes several image enhancement filters, applicable in corrosion inspection. The image enhancement filters emphasize on image features that are characteristic of surface defects created due to corrosion. The optimization image enhancement filters program can be used for image corrosion defect, as the corrosion data from the images is still intact and able to acquire for recognition process.

From the result, we can conclude that the application of several filters to enhance image in order to obtain better image for corrosion inspection is achievable. However, it is necessary to test the quality level of image resulted from single as well as multiple filtration. Furthermore, the combination of the filters could be different for different type of image.

The optimization image enhancement filter algorithm program is not limited to corrosion defect only as the filtering process optimization is based on the PSNR value. The program enhances the image quality, in conjunction to image error measurement. Proofing this situation will be our future work as we plan to apply the method to other type of images. Acquisition of the corrosion data to compare between with and without image enhancement filter algorithm will also be our next future work.

REFERENCES