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Denoising Of Radiographic Image Using Frobenius Norm Filter In VHDL

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Abstract

Denoising of radiographic image is a filtering technique to reduce noise and in which image processing techniques such as image enhancement and filtering are evolved. Denoising is carried out for feature extraction of weld defect from radiographic image Histogram equalisation with median filter and multi histogram equalisation with frobenius norm filter are applied on radiographic images and their performance is compared to find the best method. The parameter used for the evaluation of the radiographic image is peak Signal-to-Noise Ratio (PSNR), Root Mean Square Error (RMSE), Standard Deviation (SD), Mean (M). The performance of frobenius norm filter with standard filter (median filter) provides better quantitative result and hence it is adequate for feature extraction of weld defect from radiographic image.

Keywords – denoising, eigen value, eigen vector image enhancement, filtering, frobenius norm filter (FNF), histogram equalisation, median filter

1. Introduction

Radiographic Testing (RT), or industrial radiography, is a non-destructive testing (NDT) method of inspecting materials for hidden flaws and weld defect by using the ability of short wavelength electromagnetic to penetrate various materials. Either an X-ray machine or a radioactive source can be used as a source of photons. Since the amount of radiation emerging from the opposite side of the material can be detected and measured, variations in this amount (or intensity) of radiation are used to determine thickness or composition of material. Penetrating radiations are those restricted to that part of the electromagnetic spectrum of wavelength less than about 10 nanometres [8].

The beam of radiation must be directed to the middle of the section under examination and must be normal to the material surface at that point, except in special techniques where known defects are best revealed by a different alignment of the beam. The length of weld under examination for each exposure shall be such that the thickness of the material at the diagnostic extremities, measured in the direction of the incident beam, does not exceed the actual thickness at that point by more than 6%. The specimen to be inspected is placed between the source of radiation and the detecting device, usually the film in a light tight holder or cassette, and the radiation is allowed to penetrate the part for the required length of time to be adequately recorded [8].

The result is a two-dimensional projection of the part onto the film, producing a latent image of varying densities according to the amount of radiation reaching each area. It is known as a radiograph, as distinct from a photograph produced by light. Because film is cumulative in its response (the exposure increasing as it absorbs more radiation), relatively weak radiation can be detected by prolonging the exposure until the film can record an image that will be visible after development [8].

The interpretation of the radiographic film can be done automatically or by a skilled operator. For automatic interpretation of radiograph at first the image has to be digitized, and then an denoising process is carried out. Figure 1 shows the block diagram of the automatic interpretation system using GRT [1].

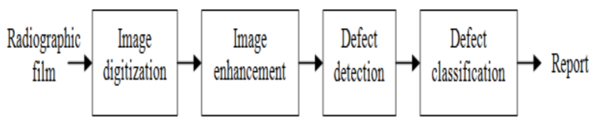

Fig 1: Block Diagram of the Automatic Interpretation System [1]

The image after digitisation undergoes denoising. Denoising is carried out to reduce noise and find the weld defect. The denoising steps are shown in figure2.

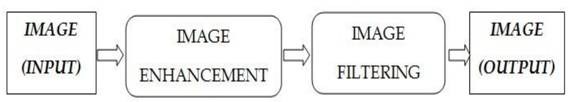

Fig 2. Steps for denoising

1.1 Image Enhancement

The purpose of image contrast enhancement methods is to increase image visibility and details

[2].The histogram equalization (HE) method is probably one of the most known contrast enhancement methods for gray level images due to its simplicity and effectiveness. The main principle of histogram equalization method is to increase the contrast of the image by equalizing its histogram into a uniform one that stretch the full graylevel range. HE is based on the assumption that for maximum transfer of information, the perceived histogram of gray levels in an image should be homogenous. It can be easily shown that the for discrete 8-bit gray scale images, the HE method achieves this by using the transformation function[2] .

1.1 Image Filtering

Image filtering is a process which is used to remove noise, sharpen contrast, or highlight weld defect in the radiographic images [1]. In most of the researches median filter is used for denoising. In the radiographic image, filtering is carried out after contrast enhancement using median, frobenius norm filters in order to select the best filter for the radiographic image filtering purpose.

Since denoising is done by using VHDL, we cannot give directly input as image. VHDL will accept text as an input in which text contains image pixel values. For conversion of image into text is done by using matlab and viceversa for getting output image. The overall process which is done in matlab and VHDL is shown in figure 3.

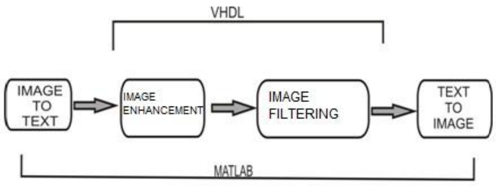

Fig 2. Overall process

2. Histogram Equalisation with Median filter

In the existing work for image enhancement histogram equalisation and for image filtering median filter is used. The median filter is a nonlinear filter used to remove noise from the image. It can potentially remove all the noise without affecting the clean pixels. It is the most frequently used filtering technique to remove impulsive noise from radiographic images [1]. Median filters are very effective in removing salt and pepper and impulse noise while retaining image details because they do not depend on values which are significantly different from typical values in the neighbourhood. Median filters work in successive image windows in a fashion similar to linear filters. However, the process is no longer a weighted sum. The median filter considers each pixel in the image and looks at its nearby neighbours, and then replaces the pixel value with the median of neighbouring pixel values. For example, take a 3 x 3 window and compute the median of the pixels in each window centered around [i, j]. The median is calculated by first sorting all the pixel values from the surrounding neighbourhood, and then replacing the pixel being considered with the median value [1]. The main idea of the median filter is to go through the signal entry by entry and replacing each entry with the median of neighbouring entries. The neighbouring pattern called the "window", which slides, entry by entry, over the entire signal. For 1D signal, the most absolute window is just the first few preceding and following entries, whereas for 2D (or higher-dimensional) signals such as images,bigger matrix, more complex window patterns are possible (such as box or cross patterns). It has to be taken as note when window has an odd number of entries, then the median is is just the middle value after all the entries in the window are sorted numerically [6]. Figures 3 show the working of median filter.

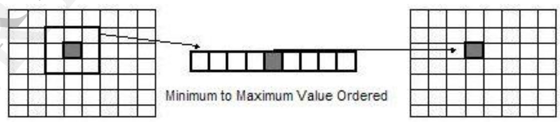

Fig 3. Median filter sliding window []

3. Multi Histogram Equalisation with Frobenius norm Filter

In the proposed work for image enhancement histogram equalisation and for image filtering frobenius norm filter is used. This filter uses frobenius norm for denoising. The Frobenius Norm can be computed from the matrix entries $a_{j,k}$, j,k = 1,..d of matrix A having eigen values $\lambda_1(A)$, ... $\lambda_d(A)$ as :

$$\| A \|_F = \sqrt{\sum_{j=1}^{d} |\lambda_j|^2} = \sqrt{\sum_{j,k}^{d} a_{j,k}^2} \qquad (1)$$

The Frobenius Norm works on Eigen values, Eigen vectors, which are similar to a given system. When applied to a neighbourhood of pixels, the connectivity is preserved even when the image is highly corrupted. FNF gives good results even when the window size is large. The Frobenius Norm is a sub-multiplicative measure and is useful for adaptive optimization of a denoising algorithm where the noise model's PDF can be measured within the Norm [4].

Here we are taking 256*256 matrix, the whole matrix cannot be multiplied with eigen vector. So we are taking 3*3 matrix from the main matrix and calculating eigen values for each window set (3*3 matrix). If we multiply any square **A** matrix with n rows and n columns by such a vector V, then the resultant will be another vector W = A*V, also with **n** rows and one column. i.e,

$$\begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} A_{1,1} & A_{1,2} & \cdots & A_{1,n} \\ A_{2,1} & A_{2,2} & \cdots & A_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{n,1} & A_{n,2} & \cdots & A_{n,n} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix}$$

where, for each index i,

$$w_i = A_{i1}v_1 + A_{i2}v_2 + \cdots + A_{in}v_n = \sum_{j=1}^{n} A_{ij}\, v_j$$

Generally, if v is not all zeros, then vectors v and Av will not be parallel. But when they *are* parallel (that is, when there is some real number λ such that Av=λv) we can state that v is an eigenvector of A. In that case, the scale factor λ is said to be the eigen value corresponding to that eigenvector [7].

In particular, multiplication by a 3×3 matrix A may change both the direction and the magnitude of an arrow v in three-dimensional space. However, if v is an eigenvector of A with Eigen value λ, the operation may only change its length, and either keep its direction or flip it (make the arrow point in the exact opposite direction). Specifically, the length of the arrow will increase if $|\lambda| > 1$, remain the same if $|\lambda| = 1$, and decrease it if $|\lambda| < 1$. Moreover, the direction will be precisely the same if $\lambda > 0$, and flipped if $\lambda < 0$. If $\lambda = 0$, then the length of the arrow becomes zero [7].

After the above step we will get a cubic equation in a form

$$a_3x^3 + a_2x^2 + a_1x + a_0 = 0$$

This should be simplified by solving the cubic equation.

Let,

$$Q = \frac{3a_1 - a_2^2}{9}$$

$$R = \frac{9a_2a_1 - 27a_0 - 2a_2^3}{54}$$

$$D = Q^3 + R^2$$

$$S = \sqrt[3]{R + \sqrt{D}}$$

$$T = \sqrt[3]{R - \sqrt{D}}$$

The roots of the cubic equation are given by,

$$Z_1 = -\frac{1}{3}a_2 + (S+T)$$

$$Z_2 = -\frac{1}{3}a_2 - \frac{1}{2}(S+T) + \frac{1}{2}i\sqrt{3}(S-T)$$

$$Z_3 = -\frac{1}{3}a_2 - \frac{1}{2}(S+T) - \frac{1}{2}i\sqrt{3}(S-T)$$

(These three equations (z1, z2, z3) giving the three roots of the cubic equation are sometimes known as Cardano's formula. The equation for z1 in Cardano's formula does not have an *i* appearing in it explicitly while z2 and z3 do, but this does not say anything about the number of real and complex roots (since *S* and *T* are themselves, in general, complex). However, to determine which roots are real and which are complex can be achieved by nothing that if the polynomial discriminant $D > 0$, one root is real and two are complex conjugates; if $D = 0$, all roots are real and at least two are equal; and if $D < 0$, all roots are real and unequal [5]. If $D < 0$, define

$$Z_1 = 2\sqrt{-Q}\cos\left(\frac{\theta}{3}\right) - \frac{1}{3}a_2$$

$$Z_2 = 2\sqrt{-Q}\cos\left(\frac{\theta + 2\pi}{3}\right) - \frac{1}{3}a_2$$

$$Z_3 = 2\sqrt{-Q}\cos\left(\frac{\theta + 4\pi}{3}\right) - \frac{1}{3}a_2$$

Then,

$$\sqrt{\sum_{j,k}^{d} a_{j,k}^2} = z1*z1+z2*z2+z3*z3$$

Then,

$$\| A \|_F = \sqrt{\sum_{j=1}^{d} |\lambda_j|^2} = \sqrt{\sum_{j,k}^{d} a_{j,k}^2}$$

The median values in the matrix is replaced with eigen value if the matrix minimum and maximum value should not be less or exceed the eigen value respectively or else it will taken the median value and the value will be replaced in main matrix.

4. Experimental Results

The radiographic image which is 256*256 matrix which is dull and noisy which is processed with FNF for denoising is shown in fig 4 and fig 5 VHDL simulation waveform. FNF is compared with standard filter (median filter) to show that FNF is capable of reducing noise and it is adequate.

Fig 6 is output image and fig 7 is VHDL simulation waveform after the process HE with median filter. Fig 8 is output image and fig 9 is VHDL simulation waveform after the process HE with FNF.

The calculation of the square root of the summation of squared distance between the image neighbouring pixels is the most computationally intensive procedure in the proposed method algorithm .One property of medians, which increases the computationally complexity is that it is independent of the norm, thereby causes quite an inconvenience, [4]. Another observation is that the performance of the algorithm was consistent across the whole test data set [4]. Qualitative analysis is done by observing output images fig 6 and fig 8 which shows that HE with FNF denoises well than HE with median filter.

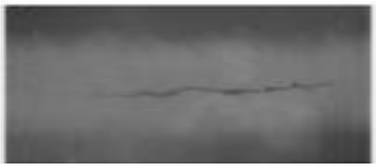

Fig 4. Input image

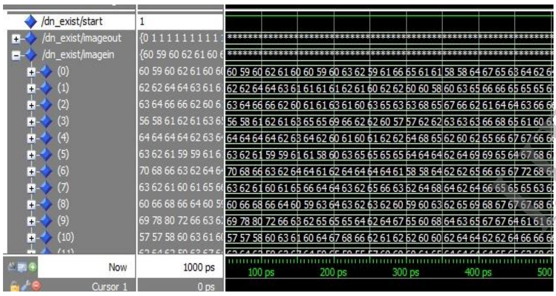

Fig 5. Input waveform

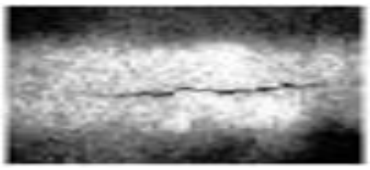

Fig 6. HE with Median filter output image

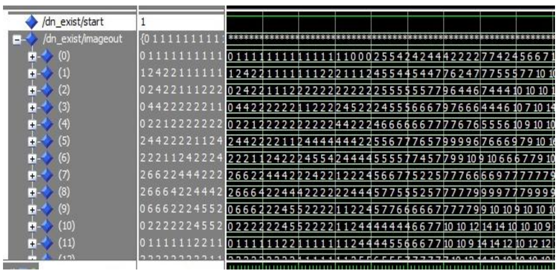

Fig 7. HE with Median filter output waveform

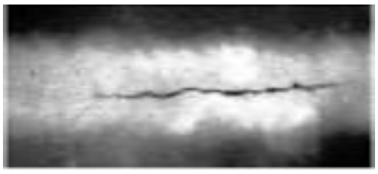

Fig 8. HE with FNF output image and its waveform

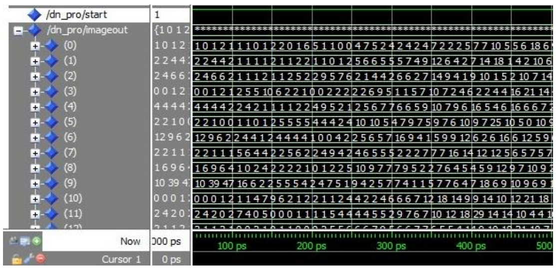

Fig 9. HE with FNF output image and its waveform

Quantitative evaluation shows that histogram equalisation with frobenius norm filtering method showed better result than histogram equalisation with median filter.

Table 1. Quantitative analysis

PARAMETER / METHOD	PSNR	RMSE	MEAN	STANDARD DEVIATION
HE WITH MEDIAN FILTER	20.2677	611.3736	198.1502	79.6956
HE WITH FNF	20.3547	599.2593	198.0003	79.9487

From table 1 we can observe that proposed work (HE with FNF) is having lowest RMSE value which leads to highest PSNR. So the median filter is less capable of reducing noise than frobenius norm filter.

From overall evaluation, it is observed that FNF is computationally more efficient than other standard filter and it is giving good result when the window is large and preserves the edges.

5. Conclusion

Denoising of the radiographic image is the major concern in the oil and petroleum industry, so from the overall conclusion by qualitative and quantitative evaluation frobenius norm filtering method is the best method for denoising than other standard filter.FNF is capable for filtering even large size window and preserving edges. Feature extraction process and reducing large noise blotches which is done by FNF .Hence frobenius norm filtering is used for denoising of radiographic image.

6. Reference

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