FLAW DETECTION AND DENOISING OF IMAGES

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ABSTRACT: The aim of the paper is to present a method to denoise the image and to extract the features of weld defects. The preprocessing task of denoising is mandatory before feature extraction. This paper proposes multi histogram equalization with frobenius norm filter, which are applied on images and their performance is analyzed. The frobenius norm filter is better in edge preserving and capable of reducing noise in blotches and its performance is good in feature extraction. Image has to be enhanced before filtering for increasing contrast and brightness and to make the darker area bright. Multi histogram equalization technique is used instead of the oldest technique of histogram for image enhancement. The frobenius norm filter is calculating eigen values using eigen vector and finding frobenius norm and replacing the value, thereby the frobenius norm filter is better than standard median filter. The defects in the image is classified according to the shapes based on the geometric features like area, major axis, minor axis, eccentricity, perimeter, solidity, orientation and convex area using feed forward Artificial Neural Network.

KEY WORDS: Multi histogram equalization, Frobenius norm filter, Denoising,wavelet and curvelettranform.

1 INTRODUCTION

Image processing technique is used to enhance raw images taken through cameras or sensors that are placed on satellites, space probes and aircrafts or images taken in normal day-today life for various applications.Sometimes images obtained from satellites, conventional and digital cameras lack in contrast and brightness because of the limitations of imaging sub systems and illumination conditions while capturing image. An image may have different types of noise.

Image enhancement is a technique used to extractcertain image features for subsequent analysis or for image display. Examples include contrast and edge enhancement, noise filtering, sharpening, histogram modification and magnifying of the images.

The enhancement process itself does not increase the inherent information content in the data. It simply emphasizes certain specified image characteristics. Enhancement algorithms are generally interactive and application- dependent.

This paper deals about weld defect analysis and detection using enhancement algorithms to detect the flaw in a metal pipe.

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2 WELD DEFECT IMAGE ANALYSIS

Welding plays vital role in industry and is the process of joining and the inspection of welds is a very important task for assuring safety, security and reliability in mechanical industries. Non-Destructive Testing (NDT) techniques have been employed to test a material for surface or internal flaws. Radiography seems to be the most effective method to identify the most types of defects in the images. The defective areas absorb more energy and thus the defects appear darker in the image.

The weld defect images are contaminated with noise and are also blurred. In order to improve the image analysis, various digital image processing techniques such as enhancement, denoising (Ernest & Chitra,2013) and classification can be applied. Noise removal is required for improving the quality of the image to better recognize the defects. Earlier different noise removal filters such as median, kaun, weinerwere used. An image with the weld defect is shown in figure 1.

Interpretation of weld radiographs by humans is very subjective, inconsistent, labour-intensive and sometimes biased. Therefore, various automated inspection techniques for weld radiographs were attempted worldwide over the past years. Computer vision is a key factor for the implementation of total quality within the different processes in industrial automation.

The radioactive source is remotely exposed to the pipe and an image of the weld is produced on the film. This film is examined for signs of flaws in the weld.

Figure 1. Radiography image with weld defects

For automatic first the image is digitized using a digital camera or a digital scanner before an enhancement process, and after that detection and classification processes are performed. This process is described below in figure 2. After the digitization process, the produced images have small contrast between the background and the weld defect regions. Also some pronounced granularities are found due to digitization and the type of film used in industrial testing. So this paper emphasizes image enhancement to remove system noise and film noise.

2.1 Block diagram of the design flow

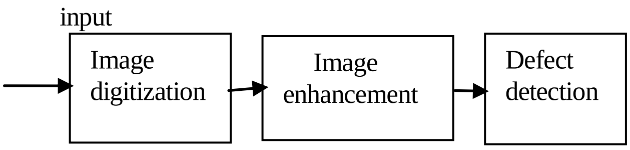

Figure 2. Block diagram of the automatic interpretation system

This paper proposes a technique which not only used to detect the flaws automatically but also offer a better visualization of information. In this method the extraction of weld defects (Hassan &.Jalil,2012), is processed in four steps. In the first step, image enhancement techniques are applied to poor quality and low contrast images through adaptive histogram equalization. In the second step noise reduction is done using median filter, kaun filter, weiner filter and lee filter. In the third step wavelet and curveletdenoising is exploited to reduce the noise in the image. In the fourth step interpolation is carried out to estimate intermediate pixels between the known pixel values by guessing the intensity values at missing locations.

Flaws occur during welding due to various reasons. The flaws are seen in the form of pores, gaps, cracks and cavities .Inspection of weld structure is essential to ensure quality of the materials and for safety and reliable operations.

2.2 Quality assessment metrics

For evaluating an image quantitatively, the parameters like Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), entropy, Standard Deviation (SD) are used.

The MSE is the arithmetic difference between the original image and the enhanced image and it measures the loss of image quality. Consider the original image F (i, j) and the enhanced image G (i, j) with size M × N, the MSE can be defined as in eq(1):

$$MSE(F.E) = \frac{1}{MN}\sum_{p=0}^{M-1}\sum_{q=0}^{N-1}(F(p,q) - E(p,q))^2 \quad (1)$$

The PSNR is the ratio between the maximum possible power of the image and the power of corrupting noise that affects the fidelity of its representation. PSNR is expressed in terms of a logarithmic dB scale, and is defined for an 8 bit level image as eq (2):

$$PSNR(F,E) = 10\,log_{10}(\frac{255^2}{MSE(F,E)}) \quad (2)$$

Lower the value of MSE and higher will be the PSNR. Here, the signal is the original image, and the noise is the error in reconstruction.

The entropy is a measure of the average information content. If P denotes the probability mass function of F, the entropy is defined by eq (3):

$$E = -\sum_{p=1}^{n} P(F_p)\log_2 P(F_p) \quad (3)$$

The standard deviation (σ) is a measure of the dispersion of a set of data from its mean (Kasban & Zahran & Arafa & El-Kordy Elaraby &. Abd El-Samie,2012) The smoothness measures the relative smoothness of the intensity in an image region as follows in eq(4).

$$S = 1 - (\frac{1}{1+\sigma^2}) \quad (4)$$

3 EXISTING ETHODOLGY

Earlier image contrast enhancement could be performed using histogram equalization method and the filtering by using median, Wiener, Lee, and Kuan filters. The existing methods are described in detail as below.

3.1 Image contrast enhancement

The Histogram Equalization (HE) method is widely used for image contrast enhancement to enhance the overall contrast and local details.Furthermore; it retains significant change in the image brightness and saturation artifacts, specifically in low contrast images. The histogram of the original image and its equalized histograms are shown in fig 3.1 and 3.2 respectively.

Image contrast can be maximized using adaptive histogram equalization by adaptively enhancing the contrast of each pixel relative to its local neighborhood for getting improved contrast in the original image.

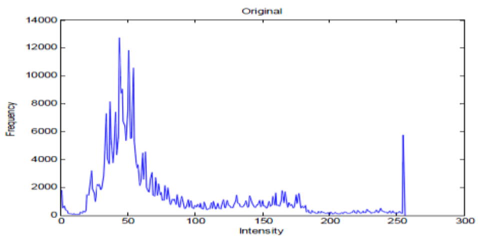

Figure 3. Original histogram

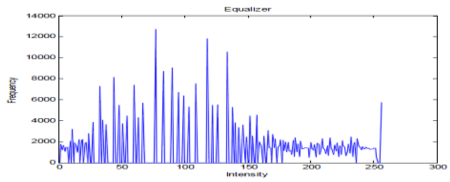

Figure 4. Equalized histogram

In this process, the histograms are calculated for small regional areas of pixels to produce local histograms, and then these local histograms are equalized or remapped from the often narrow range of intensity values to a wider range. Adaptive histogram equalization can provide better contrast in local areas than the traditional histogram equalization methods. Adaptive histogram enhances the contrast of images by transforming the values in the intensity image. It operates on small data regions (tiles), rather than the entire image. The contrast of each tile is enhanced, so that the histogram of the output region nearly matches the specified histogram.

3.2 Image filtering

When an image is acquired by a camera or any other imaging system, it is unable to use it directly for the vision system. Thus Image filtering (Dongand ShufangXu,2007).becomes mandatory to eliminate noise, sharpen contrast, and highlight contours in the images. Image filtering is carried out after the contrast enhancement using any one of filters like median (Jasdeep, 2013), Wiener, Lee, and Kuan filters, and the best filter is chosen among the four filters for the image filtering purpose. Figure 5 shows the qualitative performance of filtering of different existing filters. (Rupinderpal Kaur and Rajneet Kaur, 2013).

4 PROPOSED METHODOLOGY

In the proposed technique image enhancement and denoising is done by using multi histogram equalization and frobenius norm filter respectively for finding weld defect in the image. Enhancement increases image brightness to ease weld defect and Filtering is the technique used to reduce the noise and artifacts in the image.

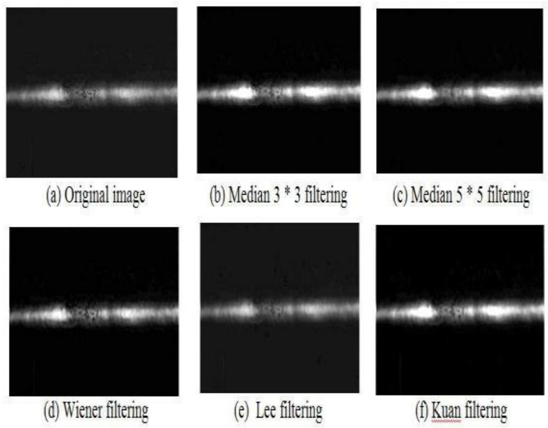

Figure 5. Denoising bydifferent filters

The earlier histogram equalization (HE) has the drawback that it tends to change the mean brightness of the image to the middle level of the gray-level range, and is not desirable in the images from the consumer electronics products. Preserving the input brightness of the image is required to avoid the generation of non-existing artifacts in the resultant image. In order to overcome this limitation, this work proposes a new technique called Multi-Histogram equalization, which consists of decomposing the input image into several sub-images, and then applying the classical histogram equalization process to each of the images.

4.1 Multihistogram equalization

This methodology performs a less intensive image contrast enhancement, in such a way that the output image represents a more natural look. The input image decomposition process is based on the histogram of the image. The histogram is partitioned into classes, which is determined by the threshold levels, where each histogram classes represent a sub-image. Based on pre determined threshold level, the histogram is divided into groups, where each of the histogram group represents a sub-image. The main key points of multi HE (David Menotti & Laurent Najman & Jacques Facon & Arnaldo de Araújo, 2007) are Contrast enhancement, Brightness preserving ability and Natural appearance. Figure 5 shows the histogram equalized input image.

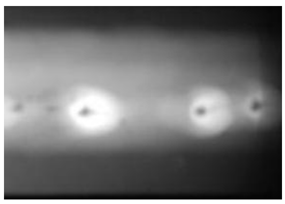

Figure 5. Histogram equalized input image

4.2 Proposed image filtering

This paper uses Frobenius Norm Filter (FNF) for denoising images. It is a spatially selective noise filtration technique in the wavelet sub band domain. This nonlinear filter is an adaptive order statistic filter functioning on the space, which modulates itself according to the noise level. It is applied to a given window set and pixel connectivity for removal of noise. This preprocess is capable of reducing large noise blotches, facilitating the feature extraction and to achieve better restoration results, especially for the high noise density noise level (Rajamani.&Krishnaveni&WassimFerose.& Kalaikamal,2012).

FNF technique is based on relational context spatial domainanalysis for the removal of additive, uncorrelated and multiplicative noise. Noise models can be considered as random variables characterized by their Probability Density Functions (PDF). The Frobenius Norm works on Eigen values, Eigen vectors and the Matrix Space, which are unique to a given system. When applied to a neighborhood of pixels, the connectivity is preserved even when the image is highly corrupted. This gives good results even when the window size is large. If the Probability Density Function (PDF) satisfies the Frobenius norm, i.e., the calculated values lie in the closed disc corresponding to the Frobenius Theorem, then the FNF replaces the corrupted pixel with the value returned by Frobenius Norm. This comparative approach leads flexibility to the Frobenius Norm Filter and it is successful in tackling different class of noises. Most set of noises are compatible with the FNF and for those that are not, the FNF algorithm assumes that the image edges are joined to form a virtual surface. Our algorithm essentially involves operations between neighboring pixels. Methods such as 4- connectivity and 8-connectivity are not used as they lead to undesirable topological anomalies. It uses connectivity in the spatial domain and exploits the group behavior of the pixel neighborhood. This Norm is often easier to compute than Induced Norms. A Matrix acts on certain Vectors, called Eigenvectors, by changing only their magnitude, and leaving their direction unchanged. It does so by multiplying the magnitude of the Eigenvector with a factor, which is either positive or negative, called Eigen value. The Eigen values of some matrices are sensitive to perturbations. Every space consists of equivalence classes of functions as a density function. A Noise Model's PDF, measured in L2 (Ω) space, is compatible with the Frobenius Norm. The central pixel's output value is dependent on the local statistical information. Frobenius Norm filter adapts itself to the local properties, information surrounding a central pixel in order to calculate a new pixel value. Frobenius Norm filter is much better in preservation of the image sharpness, details and edges (sharp contrast variation), while suppressing noise.

4.3 Proposed Frobenius Norm filter algorithm

The algorithm is explained for each pixel location (i, j) as follows.

- Initialize w=3.(w=window size)
- Compute $S_{i,j}^{min,w}$, $S_{i,j}^{fro,w}$, $S_{i,j}^{max,w}$ which are minimum, Frobenius Norm and maximum of the pixel values in ci,jw , respectively
- Compute $S_{i,j}^{fro,w}$=sqrt(sum(diag(w'*w)))
- If $S_{i,j}^{min,w}<S_{i,j}^{fro,w}<S_{i,j}^{max,w}$ then go to step 5, otherwise set i= i+
- If $S_{i,j}^{min,w}<y_{i,j}<S_{i,j}^{max,w}$, then $y_{i,j}$ is not a noisy candidate, else replace $y_{i,j}$ by $S_{i,j}^{fro,w}$.

Denote x(n,m) as a neighborhood of coefficients clustered around this reference coefficient. In general, the neighborhood may include coefficients from other subbands (i.e., corresponding to basis functions at nearby scales and orientations), as well as from the same subband. In our case, we use a neighborhood of coefficients drawn from two subbands at adjacent scales, thus taking advantage of the strong statistical coupling observed through scale in multiscale representations which are innate to the Wavelet Transform. The portrayal of salient image features such as edges and contours is consistently improved while no perceivable artifacts are introduced. Frobenius Norm (SutanshuSaksenaRaj, 2010) is based on the analysis of the statistical properties of the noise model and does not involve calculations more than unlike the Adaptive Median Filter (AMF). Thus it is computationally more efficient than Adaptive Median Filter (Gebreyohannes & Dong-Yoon,2011) gives good results even when the window size is large and provides an adaptive edgepreserving regularity as well. There is no over-smoothing of edges or smudging within the periphery of the image (Shekar & Srikanth, 2011).

5 AUTOMATIC THRESHOLDING CRITERIA

There are two methods for thresholding of the resulting wavelet coefficients. They are hard thresholding and soft thresholding. In case of hard thresholding, the coefficients with absolute values below the threshold value are set to zero. The soft thresholding decreases the magnitude of all other remaining coefficients by the threshold value. Hard thresholding keeps the scale of the signal as such but it leads to ringing and artifacts after reconstruction because of discontinuity in the wavelet coefficients. Soft thresholding overcomes this discontinuity resulting in smoother signals but soft thresholding slightly decreases the magnitude of the reconstructed signal.

5.1 Proposed Frobenius Norm filter algorithm

The following table 1 shows the comparison of various wavelets such as haar, daubechies, symlet and biorthogonal wavelet with different decomposition levels .

Table 1. The comparison of various wavelets

DL	WAVELET	RMSE	PSNR	ENTROPY	SD
1	Harr	0.0627	24.0480	4.4197	0.1485
	Db4	0.0574	24.8252	4.4138	0.1485
	Sym	0.0575	24.8064	4.4138	0.1485
	Bior	0.0569	24.9142	4.4138	0.1485
2	Harr	0.0459	26.7672	4.5827	0.1485
	Db4	0.0539	25.3694	4.4139	0.1485
	Sym	0.0542	25.3214	4.4139	0.1485
	Bior	0.0584	24.6730	4.4140	0.1485
3	Harr	0.0502	25.9874	4.4141	0.1485
	Db4	0.0584	24.6681	4.4136	0.1485
	Sym	0.0584	24.6727	4.4139	0.1485
	Bior	0.0570	24.8791	4.4055	0.1485
Curvelet		0.0456	26.8152	4.6038	0.1485

The following table 2 depicts some of the geometric features which are extracted from the segmented images.

Table 2. Some of the geometric features

S.NO	NAME	NOTATION	DESCRIPTION
1	Area	$A = \sum_{p,q=0}^{n} apq$	actual no. of pixels in the region
2	Perime-ter	P = no. of pixels forming boundary of an object	distance around the boundary of the region
3	Major axis	$L = \sum_{p,q=0}^{n} p(apq - u)$	scalar specifying length of big axis
4	Minor axis	$e = \sum_{p,q=0}^{n} q(apq - u)$	scalar specifying length of small axis
5	Solidity	$S = \sum_{p,q=0}^{n} apq/Ac$	proportion of the pixels in theconvex hull that are also in the region
6	Convex area	$Ac = \sum_{p,q=0}^{n} apq$	specifies the number of pixelsinConvexImage
7	Eccentri-city	$E=\sqrt{1-\frac{b^2}{a^2}}$	specifies the eccentricity of the ellipse that has the same second moments as the region
8	Orienta-tion	O=angle of L	the angle between the *x*-axis and the major axis of the ellipse

6 RESULT ANALYSIS

For weld defect detection and classification, an input image with weld defect is taken. Figure 6 shows the input of an image obtained in MATLAB.

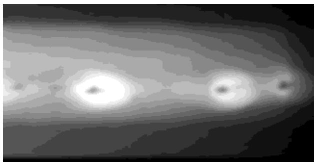

Figure 6. Input image

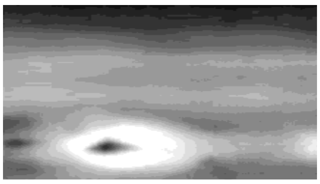

Figure 7. Multi histogram equalized red band image

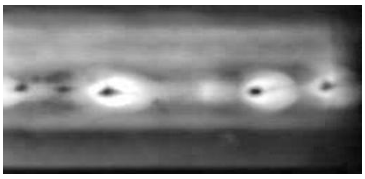

Figure 8. Multi histogram equalized

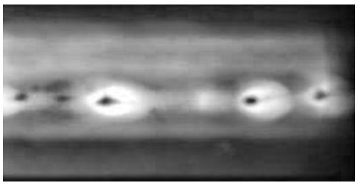

Figure 9. Multi histogram equalized blue band image

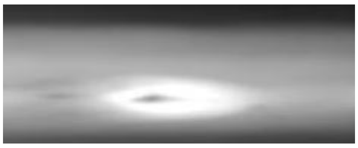

Figure 9. Multi HE input image

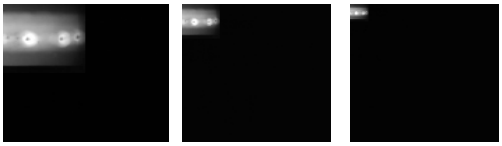

Figure 10. Haar wavelet image

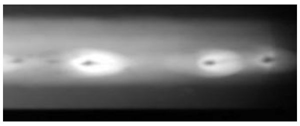

Figure 12. Wavelet denoised image

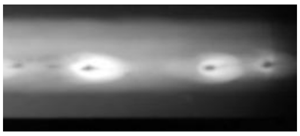

Figure 13. Curvelet denoised image

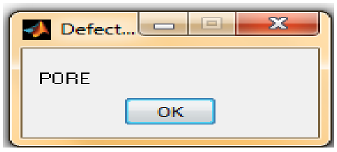

Figure 14. Pore defect in the input image.

6.1 Results for various defects

Figure 15. Worm hole defect in the input image.

Figure 16. Longitudinal crack defect in the input image.

Figure 17. Transverse defect in the input image

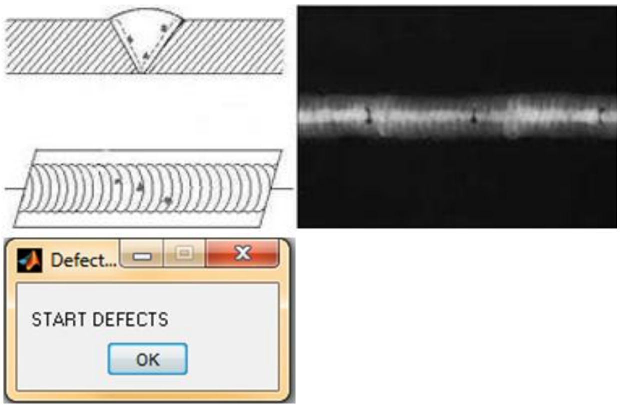

Figure 18. Star defect in the input image

7 CONCLUSIONS

This paper dealt with the denoising of image and weld defect classification in which the image is denoised using frobenius norm filter and weld defects were classified using feed forward artificial neural network. (Yahia & Belhadj & Brag & Zghal 2011), The results have been evaluated qualitatively and quantitatively considering the metrics like PSNR, RMSE, standard deviation, smoothness, entropy. It is proposed and tested a new framework called MHE for image contrast enhancement and brightness preserving which generated natural looking images. The experimental results showed that our methods is better on preserving the brightness of the processed image in relation to the original image and yields images with natural appearance, at the cost of contrast enhancement. An objective comparison among all the HE methods using quantitative measures, such as the PSNR , brightness and contrast were performed and an analysis showing the boundaries of the HE technique and its variations for contrast enhancement, brightness preserving and natural appearance.

Denoising of the 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 was done by FNF.Hence frobenius norm filtering is advantageous for denoising of image.

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