12th A-PCNDT 2006 – Asia-Pacific Conference on NDT, 5th – 10th Nov 2006, Auckland, New Zealand

A COMPARATIVE STUDY ON THE PERFORMANCE OF THE CLASSICAL AND WAVELET BASED EDGE DETECTION FOR IMAGE DENOISING ON DEFECTIVE WELD THERMOGRAPHS

N.M.Nandhitha[1], N.Manoharan[1], B.Sheela Rani[1] ,B.Venkataraman[2], Baldev Raj[2]

[1]Sathyabama Institute of Science and Technology, Deemed University, Chennai 600 119
[2]Indira Gandhi Centre for Atomic Research, Kalpakkam 603 102.

Defect in welded structures is a matter of serious concern. The current practice involves interpretation by inspectors and experts, of radiographs after the weld is completed which is time consuming. With greater emphasis on automation during manufacturing process, automated NDT has gained prominence. One of the Non Destructive Evaluation (NDE) techniques that is being increasingly applied for online monitoring is thermal imaging. Thermal imaging is an advanced NDE technique based on the detection of infrared radiation. IR imaging during welding is based on the fact that a good weld would produce isothermal patterns while a weld with defects or arc misalignment, etc would produce isothermal patterns which are not symmetrical. In automated/ adaptive welding system, IR images are to be captured in real time and based on the isothermal patterns the quality of welding is to be judged. Once thermal features are detected and attributed to defects, it is necessary to quantitatively characterize them for acceptance / rejection. Quantitative characterization requires the application of advanced image processing tools for feature extraction and dimensional measurements. Edge detection is an important image processing operation which helps in detecting the Region of Interest. Traditional approaches that use classical edge detectors work fine with high quality pictures, but often are not good enough for noisy pictures because they cannot distinguish edges of different significance as they primarily focus on the coupling between image pixels on a single scale. Recent developments in Multi Scale Analysis such as Wavelet Transform help to overcome this difficulty. Analysis of the thermal image depicting lack of penetration reveals that compared to the edge detection performance of Classical Sobel & Prewitt filters wavelet based edge detectors provide better results by removing the noise. This paper compares the performance of classical edge detector with the proposed wavelet based edge detection technique that involves multiresolution analysis which significantly improves the results.

1. Introduction

Welding is one of the widely used methods for joining metals. In spite of the numerous advances in the science and technology of welding, failures do occur and weld is still considered to be the weakest portion. Conventionally, the quality of the weld is ascertained only after the welding has been completed through the use of Non Destructive Testing (NDT) such as ultrasonic or radiography. Since each of these techniques is applied only after the welding is completed, a lot of time, material and manpower are wasted before one comes to know about the soundness of the weld.

Inherent Limitations in conventional welding processes can be overcome if the weld is continuously monitored in real time for the assessment of defects and their automatic elimination by on-line control of the welding parameters. Moreover, the defective weld can be repaired immediately without continuing the process further. This strategy to monitor, control and maintain quality of welds is commonly known as adaptive welding or intelligent welding. Intelligent welding, as the name implies, combines welding equipment with intelligent sensing and control, knowledge of human experts, and Artificial Intelligence (AI) to improve joining efficiency and reduce the weld inhomogenities and defects.

Wide variety of techniques has been reported in literature. Non-Destructive Testing sensors, which have been considered, for on-line monitoring include optical, radiography and Infrared (IR). Of the three, Infrared has the advantage that it can reveal surface and near surface perturbations. During the welding process, the position of the camera was fixed relative to the welding gun to provide measurement of temperatures in the weld pool and its vicinity. Experimental conditions were carefully maintained to minimize errors.

However, the original image is degraded by the noise incurred due to atmospheric turbulences. Image denoising is used to remove the additive noise while retaining as much as possible the important signal features. Many classical edge detectors have been developed over time. They are based on the principle of matching local image segments with specific edge patterns. The edge detection is realized by the convolution with a set of directional derivative masks. The popular edge detection operators are Roberts, Sobel, Prewitt,

FreiChen, and Laplacian operators [1-4]. They are all defined on a 3 by 3 masks, hence they are efficient and easy to apply. In situations where the edges are highly directional, classical edge detector works well because their patterns fit the edges better. But in an image corrupted with noise these edge detectors cannot distinguish actual edges from that of noise. In the recent years there has been a fair amount of research on wavelet signal de-noising [4–7] because wavelet provides an appropriate basis for separating noisy signal from the image signal.

The paper is organized as follows. Section 2 deals with thermographs of welds. Section 3 reviews classical edge detection approaches. Section 4 discusses the multiscale wavelet model for edge detection. Section 5 deals with the performance analysis and Section 6 summarises the work. The functions are implemented in Matlab [8].

2. Thermographs Of Welds

The thermal maps produced by infrared thermal imaging instruments are called thermographs. Thermograph is defined as a 2D radiance function g(x, y), where x and y denote spatial coordinates and the value of g at any point is proportional to the radiance or energy emitted from the scene at that location. Traditionally, low intensities are represented by dark shades and high intensities by bright shades. The perturbations that arise due to variations in arc positioning, heat input and due to presence of contaminants distinctly manifest as differences in the otherwise uniform spatial and temporal surface temperature distributions of thermographs.

These discontinuities of the intensity due to defects provide the locations of the object contours that are particularly meaningful for defect detection. Representation of the discontinuities or significant intensity differentials in thermographs is called edge. However due to uncontrolled illumination in and around the weld pool, thermographs have intensity differential at almost every point. But not all these differentials are edges. In thermographs, weak edges correspond to weak changes in intensity values, while strong edges correspond to significant intensity gradient. Obviously stray strong edges with no spatial coherence in magnitude and orientation are noisy edges and need to be eliminated. Hence it is needed to avoid these insignificant intensity differentials which correspond to false edges in the image due to noise are to be removed. Hence edge detection with the removal of false edges is the most important step in digital image processing.

3. Classical Edge Detection Approach And Denoising

In the most commonly used derivative approach, derivatives which yield high values at places where gray level changes rapidly are used to find edges of an image. Two dimensional derivatives for thermographs are computed with the help of edge masks. Computation of the gradient is based on obtaining the partial derivatives with respect to x and y. A digital image is divided into number of 3x3 sub images and 2-D convolution is performed on each of the sub image with the 3x3 edge detection masks. The general mask structure is shown in Fig. 1

W(-1,-1)	W(-1,0)	W(1,0)
w(0,-1)	W(0,0)	W(0,1)
W(1,-1)	W(1,0)	W(1,1)

Figure 1: General Mask structure

3.1. Prewitt mask

In Prewitt operator while approximating the first derivative, similar weights are assigned to all the neighbors of the candidate pixel whose edge strength is being calculated. Prewitt masks for horizontal and vertical edge detection are shown in Fig. 2 and Fig.3.

-1	-1	-1
0	0	0
1	1	1

Figure 2: Prewitt mask for horizontal edge detection

-1	0	1
-1	0	1
-1	0	1

Figure 3: Prewitt mask for horizontal edge detection

3.2. Sobel mask

In sobel operator, higher weights are assigned to the pixels close to the candidate pixels. Sobel masks for horizontal and vertical edge detection are shown in Fig. 4 and Fig. 5.

-1	-2	-1
0	0	0
1	2	1

Figure 4: Sobel mask for horizontal edge detection

-1	0	1
-2	0	2
-1	0	1

Figure 5: Sobel mask for vertical edge detection

However the most common problems of above edge based segmentation, are edge in locations where there is no border caused by image noise or unsuitable information in thermographs

4. Multiscale Wavelet Model For Edge Detection And Denoising

Noise commonly manifests itself as fine-grained structure in the thermograph, and wavelet transform provides a scale-based decomposition. Wavelet based edge detectors Edge detectors can be viewed as discretized wavelet functions. The convolution with edge detectors gives the wavelet transform of the image at a certain scale. Approximation of the continuous wavelet models will result in the classical edge detectors when discretized [9]. Once a continuous model is obtained, scales can be changed and objects are detected at different scale levels. Prewitt edge detector can be modeled as two orthogonal Haar wavelets.

$$A^1(x; y) = -1 \; ; \; -1{:}5 < x < 0; -1{:}5 < y \cdot < 1{:}5; \quad +1 \; ; \; 0 < x < 1{:}5; -1{:}5 < y < 1{:}5; \quad 0 \; ; \text{otherwise} \qquad (1)$$

$$A^2(x; y) = -1; \; -1{:}5 < y < 0; \; -1{:}5 < x < 1{:}5 \quad +1; \; 0 < y < 1{:}5; \; -1{:}5 < x < 1{:}5 \quad 0; \text{otherwise} \qquad (2)$$

where $A^1(x; y)$ and $A^2(x; y)$ are the wavelet coefficients and x and y are the spatial co-ordinates.

Sobel edge detector can be described as a discretized model of two orthogonal wavelets.

$$A^1(x;y) = -xe^{i((x^2+y^2)/2)} \qquad (3)$$

$$A^2(x;y) = -ye^{i((x^2+y^2)/2)} \qquad (4)$$

Where $A^1(x; y)$ and $A^2(x; y)$ are the wavelet coefficients and x and y are spatial co-ordinates.

Edge detection is performed by applying these masks as is done with conventional edge detection. But scale can be varied to obtain edges corresponding to different scales. As scale changes the edges due to noise are removed. Denoised thermographs are then subjected to morphological image processing for feature extraction and description.

5. Performance Analysis

The performance of Classical Edge Detectors and wavelet based Edge detectors are analyzed on a thermograph image of size 204 *188 of a defective weld with air gap due to lack of penetration. Original thermograph of the weld with air gap used for analysis is as shown in Fig.6.

Figure 6: Thermograph of weld with air gap

The Original image is converted to a gray scale image to reduce computational complexity as shown in Fig.7

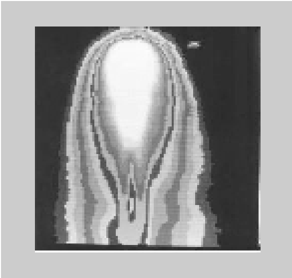

Figure 7: Gray Scale Image

The edges in the image are obtained by choosing Prewitt and Sobel filter as shown in Fig.8 and Fig.9 respectively.

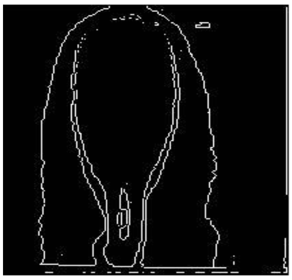

Figure 8: Edge detection using Sobel Mask

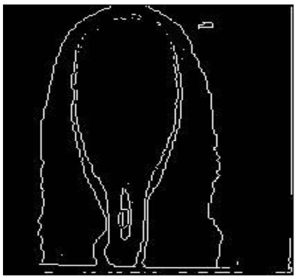

Figure 9: Edge detection using Prewitt mask

The images in Fig. 8 and Fig. 9 include the Edge due to noise also. The sobel and Prewitt masks used could not treat the edges due to noise differently from that of the image. It is because Multiscale Edge detection is not possible with the conventional Prewitt & Sobel Masks.

Wavelet based edge detectors provide a facility for varying the scaling factor, which helps in differentiating the weak edges from strong edges. The edge detected images using wavelet based Prewitt & Sobel filter are as shown in Fig. 10 and Fig. 11 respectively.

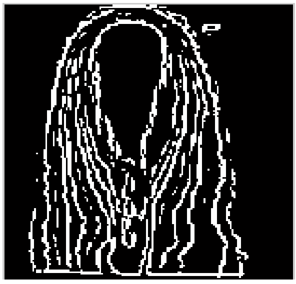

Figure 10a: Sobel based edge detection (Scaling Factor = 15)

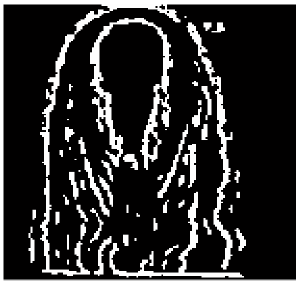

Figure 10b: Sobel based edge detection (Scaling Factor = 17)

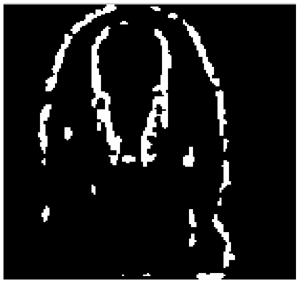

Figure 10c: Sobel based edge detection (Scaling Factor = 20)

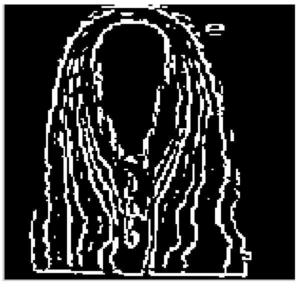

Figure 11a: Prewitt based edge detection (Scaling Factor = 15)

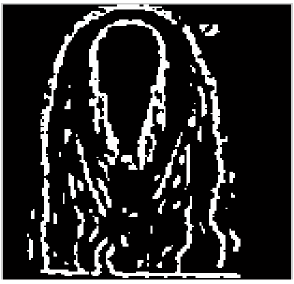

Figure 11b: Prewitt based edge detection (Scaling Factor = 17)

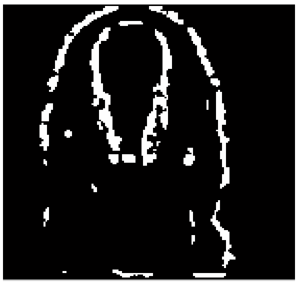

Figure 11c: Prewitt based edge detection (Scaling Factor = 20)

It is evident from the Fig.10 and Fig.11**,** which as the scaling factor varies the noise, is removed.

6. Summary

The edge detection performance of Classical Sobel and Prewitt filters are compared with the developed Wavelet based Sobel and Prewitt edge detectors. It is found that wavelet based edge detectors provide better results by removing the noise and the results are analyzed subjectively. It is the multiscale edge detection property of wavelet that has helped in removing the noise.

ACKNOWLEDGEMENT

This project is sponsored by Indira Gandhi Centre for Atomic Research, Kalpakkam, India.

REFERENCES:

[1] Mero, "A simplified and fast version of the Hueckel operator for finding optimal edges in pictures", *Pric. IJCAI*, pp. 650- 655, 1975.

[2] R.Nevatia, "Evaluation of simplified Hueckel edge-line detector", *Comput.,Graph., Image Process.*, vol. 6, no. 6, pp. 582-588, 1977.

[3] K. R. Castleman, Digital Image Processing, Englewood Cliffs, NJ: PrenticeHall, 1996.

[4] M. Hueckel, "An operator which locates edges in digital pictures", *J.of ACM*, vol.18, no. 1, pp. 113-125, 1971.

[5] D.L. Donoho ," De-Noising by Soft Thresholding", *IEEE Trans. Info. Theory 43*, pp. 933-936, 1993.

[6] S. Grace Chang, Bin Yu and M. Vattereli, "Adaptive wavelet Thresholding for Image Denoising and Compression", *IEEE Trans.Image Processing*, vol. 9, pp. 1532-1546, 2000.

[7] M. Lang, H. Guo and J.E. Odegard, "Noise reduction Using Undecimated Discrete wavelet transform", *IEEE Signal Processing Letters*, 1995

[8] MAT LAB – Image Processing Tool Box http://www.mathworks.com

[9] Jun Li, "A Report on A Wavelet Approach to Edge Detection", 2003