International Journal of Engineering & Technology, 7 (4.36) (2018) 1588-1592

SPC

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

The Effect of CLAHE and Gamma Correction in Enhancement of Digital Radiographic Image for Weld Imperfection Detection

Suhaila Abd Halim[1]*, Yupiter HP Manurung[2], Shahidan Mohamad[2], Mohamad Firhan Morni[2]

[1]Centre of Mathematics Studies, Faculty of Computer and Mathematical Sciences,
Universiti Teknologi MARA, 40450 Shah Alam, Selangor. Malaysia
[2]Faculty of Mechanical Engineering, Universiti Teknologi MARA,
40450 Shah Alam, Selangor. Malaysia
**Corresponding author E-mail: suhaila@tmsk.uitm.edu.my*

Abstract

Conventionally, the quality and acceptance of the welded joints are evaluated manually by human expert called radiography inspector. The results from the process are slow, inconsistent and even the same expert may give different results due to the poor quality of the captured image. In order to make the inspection becomes reliable, image processing could be adopted to improve and enhance the quality of the image. The purposes of this paper are to implement different image processing methods on removing image noise and enhancing image contrast, evaluate the performance image processing methods and detect weld imperfection from digital radiographic image. At the first stage, image processing is implemented on radiographic image that contains imperfection using Average Filter, Circular Averaging Filter and Gaussian Filter as noise removal while Contrast Limited Adaptive Histogram Equalization (CLAHE) and Gamma Correction (GC) as the image contrast enhancement. Then, the existence of the imperfection in processed image is extracted using Region Growing. The development of the algorithm is implemented using MATLAB 2009a. The results of the application of image processing methods show some improvement in term of accuracy as compared with manual inspection by radiography inspector. Hence, it could reduce the cost of inspection process in term of labor and time.

Keywords: *Digital Radiography; MATLAB; CLAHE; Gamma Correction; Region Growing.*

1. Introduction

Industrial radiography is a major element of non-destructive testing (NDT). It is a method to inspect hidden flaws in material using the ability of X-rays and Gamma rays to penetrate various materials. In this project, industrial radiography method is focus on inspecting imperfections of welding in which user able to assess the weld quality without damaging the weld components [13]. There are two methods in radiography that are conventional method and digital radiography. Conventionally, radiography is used based on film where the film is placed between two screens and the screens emit light when X-rays strike them. The processed film is then view on light box. While in digital radiography, X-rays sensors have been used instead of using photographic film. The advantages include time efficiency through chemical processing and ability to digitally transfer and enhance images. Besides, less radiation can be used to produce an image of similar contrast to conventional radiography.

The radiographic image processing is used to improve the image quality, making the analysis process easier, which consists of detecting and classifying imperfections on film. In the conventional method, the analysis is done exclusively by the radiograph inspector. The manual inspection on imperfections by certified inspector is based on visual characteristics such as location, shape, length, density and others. The progresses in computer science and the artificial intelligence techniques have allowed the imperfection classification to be carried out by using pattern recognition tools. These make the process automatic and more reliable. Digital image processing covers the set of the processes of improvement and extraction of qualitative information in digital images, according to the required users and needs.

Imperfection can be defined as an interruption of the typical structure of a material, such as lack of homogeneity in its mechanical, metallurgical, or physical characteristics. An imperfection could be the result of a defect, but it is not necessarily a defect. A defect, on the other hand, is an imperfection that by nature or accumulated effect such as crack length renders a part or product that unable to meet minimum applicable acceptance standards or specifications. A defect results in rejection of the part or product. Weld imperfections often detected through visual inspection. Some are detected with inspection methods such as radiography, ultrasonic, liquid penetrate, and magnetic particle inspection. The maximum acceptable limitations for these imperfections depend on the performance requirements of the welded component and as specified in the appropriate welding code, standard, or specification. The welding inspector often is required to determine the extent of imperfections and to establish their acceptance or rejection based on the relevant acceptance criteria.

Due to advancement in technology, digital radiography has been slowly replacing conventional film radiography. In digital radiography, less radiation is used to produce an image with similar contrast to conventional film method. It also provide immediate image preview where users can easily interpreted and enhanced the image using image processing method. Conventionally, the qualities of the welded joints are evaluated manually by human expert. But, nowadays the number of skilled inspector is decreasing day by day. Besides that, the results from the process is slow, inconsistent and even the same expert may give different results on the same image [14]. The inconsistent results also due to the degradation of noise and uneven distribution of image contrast in raw images. In order to assist radiographer in improving imperfections inspection results, computerized environment involving image processing techniques can be developed.

The objectives of this paper are to improve the quality of radiographic image using noise removal and contrast enhancement methods, to evaluate the performance of the methods and to detect the welding imperfection from digital radiographic image. Image processing also important in detection of imperfections and damage in aircraft structures. It is used to eliminate noise and background artifacts, smooth the sharp edge and remove detail in small objects [15].

The rest of this paper is organized as follows. Section 2 and Section 3 present overview of the image processing and segmentation processes. Section 4 presents the methodology that contains the overall implementation in this paper. Section 5 provides the experimental results that illustrate the performance of the proposed method. Finally Section 6 gives the conclusion of this paper.

2. Image Processing

Images are often affected by the changes in surrounding environment during the capturing process. This could affect the quality of the captured image in which these images might demand enhancement process for them to be acceptable for further investigation. There are two main processes involved in image processing, those are noise removal and contrast enhancement. Noise removal aims to remove image noise that cause disturbance to the image. Some filters are efficient but blurring the image. Singh and Neeru [11] investigated on the various image denoising filters under spatial domain in order to compare their performance in removing different types of noise. Gaussian filter is the simplest low pass filter that is effectively removing the high frequency noises. Average filter calculates the average of all intensities and replace it in the central pixel. It is used to remove irrelevant details from an image and give the blurring effect also. Circular Averaging filter is a pillbox that has the unique feature of being circularly symmetric [12].

Contrast enhancement is the adjustment of image contrast due to the high or low illuminance intensity in image. Pixel domain contrast enhancement is widely used due to the low requirement in terms of computational cost and parameter setting [2]. Gamma correction (GC) is a popular pixel domain contrast enhancement method because it is cost effective and good dealing with bright and blurred images [3,6,7,8]. Histogram equalization also a widely used technique but it does not always give satisfactory results for the over enhancement. Contrast Limited Adaptive Histogram Equalization (CLAHE) has controllable parameter to limit the contrast and the technique is successfully enhancing the low contrast images [10].

3. Image Segmentation

Image segmentation aims to divide image into different segments that having similar characteristics. There are several segmentation techniques can be applied to perform required segmentation process. Kaur and Kaur [9] reviewed various image segmentation techniques and listed their advantages and disadvantages. Fidali et al. [4] investigated the performance of region growing, region merging, region split and merge, k-means clustering, Otsu thresholding, Watershed transformation on infrared image sequence during the welding process. Each method gave different results and based on subjective estimation, region growing is the most beneficial approach. Thresholding is the simplest method for image segmentation. A threshold value is used to separate the foreground objects from the background image. This method is simple and fast but no guarantees the connectivity of the object in image [1]. Region growing is fast, robust and free of tuning parameters but the algorithm unable to generate seeds automatically and produce unconnected pixels [5]. Region growing separate the region in image based on the growing of seeds which normally manually selected.

4. Methodology

It starts from the overall project flow chart followed by the process of each step. Methodology gives elaboration and information about the project starting from the literature review collection until the application of segmentation method. The overall processes of image processing until segmentation methods are coded using MATLAB R2009a.

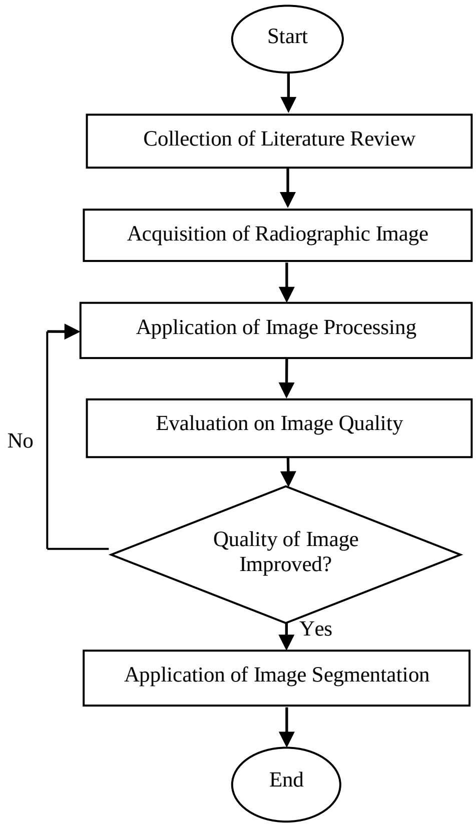


Fig. 1: Flow Chart of Imperfection Detection.

In the stage of literature review collection, the background concept to construct the research study is investigated. Then, image acquisition is a process of obtaining digitized image from real source. In this project, Phoenix µ-focused digital radiography machine as shown in Figure 2 is used. The machine is located at Faculty of Mechanical Engineering, Universiti Teknologi MARA Shah Alam.

Fig. 2: Phoenix µ-Focused Machine.

Figure 3 represents a sample of welded flawed specimen that contains imperfection that is used in the implementation stage.

Fig. 3: Sample of Welded Flawed Specimen.

Direct digital radiography process is applied in the implementation to capture radiographic image of welded flawed specimen. The image is then directly stored in the computer digitally. For acquisition process, the specimen is arranged between the detector and x-ray tube inside the Phoenix µ-focused machine as illustrates in Figure 4.

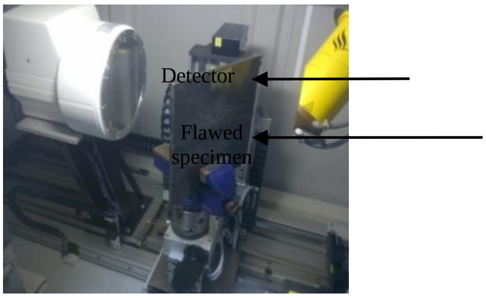


Fig. 4: The Arrangement of Specimen in Phoenix µ-Focused Machine.

After the acquisition process, digital radiographic image is produced. Figure 5 shows five (5) samples of original image that contain different imperfection.

Image 1

Image 2

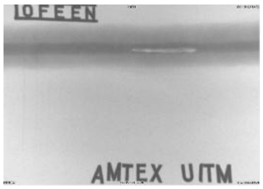


Image 3

Image 4

Image 5

Fig. 5: Original Image

Then, image processing technique is applied to process the original image in order to improve the quality of the image to be visually pleasant. This step is involved the noise removal of Average filter (Ave), Circular Averaging filter (Disk) and Gaussian filter (Gauss).

After the denoising process, the image is then processed using contrast enhancement method of GC and CLAHE. The CLAHE seeks to reduce the noise produced in homogeneous areas by basic adaptive histogram equalization.

GC operation performs nonlinear brightness adjustment. Brightness for darker pixels is increased, but it is almost the same for bright pixels. If gamma is 1 (the default), the mapping is linear. If gamma is less than 1, the mapping is weighted toward higher (brighter) output values. If gamma is greater than 1, the mapping is weighted toward lower (darker) output values. The processed image is produced after the application of image processing methods. Both processes of noise removal and contrast enhancement produced processed image.

Then, the quality performances between processed and original images are evaluated using Peak Signal to Noise Ratio (*PSNR*) as in (1) and Average Difference (*AD*) as in (2).

$$PSNR = 10\log_{10}\frac{MAX_I^2}{MSE} = 10\log_{10}\frac{255^2}{MSE}. \quad (1)$$

in which

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left[x_{i,j} - x'_{i,j}\right]^2$$

$$AD = \frac{\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}\left(x_{i,j} - x'_{i,j}\right)}{mn} \quad (2)$$

where:

mn = image dimension in row (i) and column (j)

MAX_I = maximum value of image pixel value

$x_{i,j}$ = pixel value at i and j of original image

$x'_{i,j}$ = pixel value of i and j of processed image

In detecting the imperfections, segmentation technique of region growing is implemented. An initial seed point on image region of interest (ROI) that contains imperfection is selected manually by user. Different selection of seed point gives different segmentation results.

5. Results

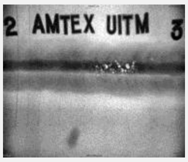
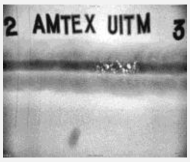
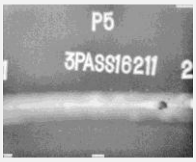
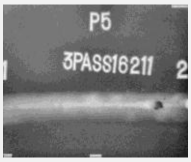
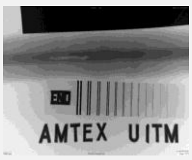
The image quality between the original image and the processed image are measured by using two metrics of *PSNR* and *AD*. Table 1 illustrates the performance of quality measurement for five different imperfections.

Table 1: Image Quality Metric

Image	Contrast	*PSNR*			*AD*		
		Ave	Disk	Gauss	Ave	Disk	Gauss
Image 1	CLAHE	14.050	13.731	**17.881**	27.475	31.365	**18.449**
	GC	30.555	27.723	**31.723**	6.1555	6.2725	**3.679**
	CLAHE With GC	18.330	13.916	**19.031**	21.259	32.219	**17.042**
Image 2	CLAHE	13.176	14.071	**14.902**	28.14	46.082	**21.073**
	GC	27.413	**30.528**	29.189	9.6244	8.1397	**4.748**
	CLAHE with GC	21.363	**21.366**	21.223	10.57	11.064	**10.303**
Image 3	CLAHE	10.843	10.818	**24.191**	60.783	61.755	**54.721**
	GC	29.723	28.447	**32.618**	5.4757	5.5129	**4.379**
	CLAHE with GC	18.225	**19.569**	18.886	26.785	**20.694**	24.642
Image 4	CLAHE	12.062	12.398	**16.665**	17.387	**16.864**	28.879
	GC	30.082	27.750	**30.780**	**6.2076**	6.3618	6.278
	CLAHE with GC	20.667	20.527	**20.880**	9.2643	**9.1585**	9.489
Image 5	CLAHE	13.589	13.751	**15.374**	28.652	**21.668**	47.235
	GC	26.865	28.120	**28.937**	9.8345	**6.5782**	8.280
	CLAHE With GC	20.395	20.349	**20.870**	13.184	12.938	**11.631**

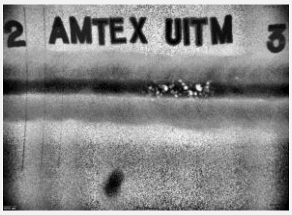
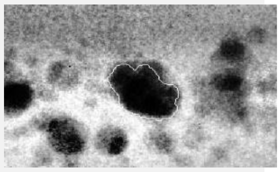
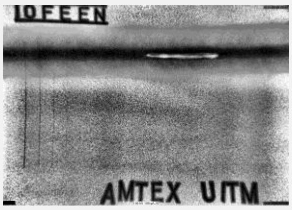
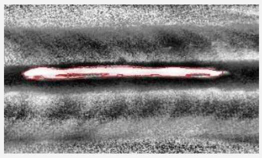
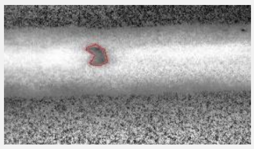
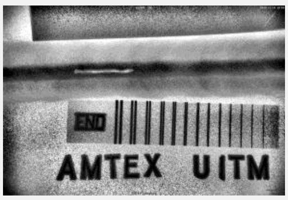
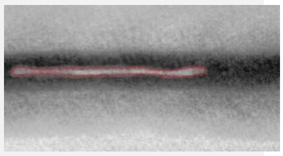
The highest value of PSNR in bold and the lowest value of AD in bold indicate the best quality improvement compared with original image. It can be observed that, on the average, Gaussian filter gives the highest PSNR value and the lowest AD value.
Table 2 shows the result on radiographic image after both noise removal and contrast enhancement. Based on the results in Table 1, Gaussian filter is selected as noise removal for further contrast enhancement that is CLAHE, GC and combination of both.

Table 2: Results of Radiographic Images after Image Processing

CLAHE	GC	CLAHE with GC
		
		
		
		
		

By observation on Table 2, the existence of imperfection is highlighted after the process of Gaussian filter and the CLAHE with GC. The existences of imperfection in the processed image are much clearer as compared with the original image. This could assist in interpreting the existences of imperfection accurately in analysis stage.
Table 3 demonstrates the segmentation results for five images with different imperfections using Region Growing. The region growing is applied on image ROI and produced segmented image of imperfection.

Table 3: Segmentation Results

Processed Image	**Segmented Image with ROI**
	
	
	
	
	

6. Conclusion

The capability of noise removal and contrast enhancement of digital radiographic image is important in order to improve the quality of image for further inspection process. A good quality of image can be used by radiographer in assisting them to accurately detect the existence of imperfection on digital radiographic image during inspection process and hence assists them in making accurate decision. The objectives of this paper are successfully achieved by implementing image processing methods, measure the quality of image and detect the imperfection from the radiographic image. Two methods of image enhancement used in this paper which are GC and CLAHE while the image quality are measured using PSNR and AD. In order to detect the imperfection, Region Growing with manual selection of seed point is applied. As for future work, there are some recommendations related to this paper that are automatically select the seed point for region growing to reduce the processing time of detection.

Acknowledgement

We would like to thanks to Faculty of Mechanical Engineering, Universiti Teknologi MARA (UiTM) Shah Alam for the financial support and giving us the opportunity and providing facilities to conduct this study.

References

[1] Anjna E & Kaur ER (2017), "Review of Image Segmentation Technique," *International Journal of Advanced Research in Computer Science*, Vol. 8, No. 4, pp. 36-39.
[2] Cao G, Huang LH, Tian HW, Huang XL, Wang YB & Zhi RC (2018), "Contrast Enhancement of Brightness-Distorted Images by Improved Adaptive Gamma Correction," *Computers & Electrical Engineering* (66), pp. 569-582.
[3] Cao G, Zhao Y, Ni R & Li X (2014), "Contrast Enhancement-based Forensics in Digital Images," *IEEE Trans. Info. Forensics and Security*, Vol. 9, No. 3, pp. 515-525.
[4] Fidali M, Jamrozik W, Bzymek A & Timofiejczuk A (2013), "Segmentation of Welding Arc Images for Purposes of Welding Diagnostics," *Diagnostyka*, Vol. 14, No. 1, pp.11-18.
[5] Gomez O, Gonzalez JA & Morales EF (2007), "Image Segmentation using Automatic Seeded Region Growing and Instance-Based Learning," *CIARP'07 Proceedings of the Congress on Pattern Recognition 12th American Conference on Progress in Pattern Recognition, Image Analysis and Applications*, pp. 192-201.
[6] Gonzalez RC & Woods RE (2006), Digital Image Processing, 3rd ed. Upper Saddle River, NJ, USA: Prentice-Hall.
[7] Huang L, Cao G, & Yu L (2016), "Efficient Contrast Enhancement with Truncated Adaptive Gamma Correction," *Proc. of IEEE Intl. Congress on Image and Signal Process. BioMedical Engineering and Informatics*, pp. 189- 194.
[8] Huang SC, Cheng FC, & Chiu YS (2013), "Efficient Contrast Enhancement with Adaptive Gamma Correction," *IEEE Trans. Image Process*, Vol. 22, No. 3, pp. 1032-1041.
[9] Kaur D & Kaur Y (2014), "Various Image Segmentation Techniques: A Review," *International Journal of Computer Science and Mobile Computing*, Vol. 3, No. 5, pp. 809-814.
[10] Nahar B (2012), "Contrast Enhancement with the Noise Removal by a Discriminative Filtering Process," Concordia University Montreal, Quebec, Canada.
[11] Singh I & Neeru N (2014), "Performance Comparison of Various Image Denoising Filters under Spatial Domain," *International Journal of Computer Applications (0975 – 8887)* 96(19), pp. 21-30.
[12] Smith SW (1998), "Linear Image Processing," *The Scientist and Engineer's Guide to Digital Signal Processing*.
[13] Thai WKF (2008), "Development of A Computed Radiography-Based Weld Defect Detection and Classification System," Universiti Sains Malaysia.
[14] Vamos G, Lovanyi I, Nagy A & Kiss B (2002), "Flaw detection in metallic fusion welds on X-ray images using Bayesian networks," *Proceedings of first Hungarian conference*, pp 118–123.
[15] Wang X, Wong BS, Tui CG, Khoo KP & Foo F (2006), "Image Enhancement for Radiographic Non-Destructive Inspection of The Aircraft," *12th A-PCNDT 2006 – Asia-Pacific Conference on NDT*.