Image Enhancement and Noise Filtering of Ischemic Stroke in CT and MRI Brain

Mutiara bt Malek
Faculty of Health Sciences
MARA University Technology
Puncak Alam Campus
mutiemalek@gmail.com

Nor Afifah bt Mohd Ali
Faculty of Health Sciences
MARA University Technology
Puncak Alam Campus
norafifah.mohdali@gmail.com

Nur Hidayah bt Mohd Noor
Faculty of Health Sciences
MARA University Technology
Puncak Alam Campus
nurhidayahmohdnoor23@gmail.com

***Abstract*— Ischemic stroke is a condition of dysfunction of certain area in brain due to the decreasing blood supply. The stage of the ischemic stroke can be diagnose by having the CT or MRI of brain. However, the provided information in images from both modalities may contaminated by noise and poor contrast. Noise will degrade the image formation by appeared as irregular granular pattern in the images. Radiographic contrast can be defined as the differences of the degree of density between two adjacent areas. It plays an important role for the observer to distinguish features of interest, for example, defects from the surrounding area. Hence, image enhancement and noise filtering must be applied to improve the image quality and eliminate the distribution of the extreme noise. From the result of study, both adaptive filtering and wiener filtering can be used in removing the noise in order to enhance visualization of the location of infarction or embolism occurs from the ischemic stroke. Another filter method used is averaging filtering which also have the same purpose to eliminate the noise. Then, the image must undergo sharpened process by using unsharp masking to improve the blurring effect. This method can also demonstrate early stroke changes by enhances the detail and resolution of the cortical sulci. Besides, to enhance the image, contrast-limited adaptive histogram equalisation is used to produce the clearer details and brighter of the output images. It enhanced the right lateral horn of the frontal lobe which narrowed that indicate the present of hemorrhage which are one of the factors of ischemic stroke. In addition, the image enhancement by the negative transformation highlight the transformation of original image, T1-weighted image to appear almost similar with the T2-weighted image as their hypointense region previously become slightly hyperintense on the negative image.**

Keywords-ischemic stroke, adaptive filtering, wiener filtering, averaging filtering, unsharp masking, adaptive histogram equilisation, negative transformation

I. INTRODUCTION

Digital image processing is a processing digital image by means of a digital computer which compromise the finite number of elements, pixel. Every image that produces using the imaging modalities can undergo process of an area of containing the text, preprocessing, extracting individual character of desirable character through computer processing [1]. Different imaging modalities will help to give out the information and allowed to make the diagnosis. In this case , the computed tomography produce image by using multiple x-rays while magnetic resonance imaging [2] produce image by the interaction between magnetic field from magnetic bore and the radio wave. Next, their image quality is affected by several factors for example noise and contrast [2].

Ischemic stroke are one of the vascular disease that cause by the blood clots that severely cause block to the blood flow hence form vessel occlusion. Ischemic stroke can occur in two ways: 1) Infarction caused by the thrombosis of a cerebral artery and 2) Embolism to the brain from a thrombus elsewhere in the body. This kind of disease can be easily diagnosed using the CT or MRI. Commonly, non-contrast brain CT scans are preferable especially before treatment with thrombolytic agents. Followed-up by MRI, traditionally T1 and T2 brain protocol for imaging onset of an ischemic stroke and in many cases it is more accurate than CT [3]. The image that obtained in this project containing either noise or lack in image enhancements, hence by applying certain noise removal and image enhancement function it will maximize the image appearances so that the image easily to perceived by the observer and subsequently allowed for the diagnosis to occur by the physician.

Normally, image appearance on CT will be loss of contrast between gray matter and white matter and the MRI image will have hyperintense signal on white matter and loss of arterial flow which indicate irreversible ischemic brain damage.

II. LITERATURE STUDY

Adaptive filtering is one of the method used in many applications in order to remove the noise in the image. It is linear dynamical system with the basic processes of digital filtering. It has the capability to modify the values of parameters or coefficients used in the filter in order to generate the output signal without degradation, noise and interface signal. The characteristic of the whole adaptive filter is mainly influenced by the choice of the filter structure and the criterion function used during the adaptation process. Lee et al. (2007) stated that the adaptive filter was selected to enhance the conspicuity of gray matter interface changes to hypoattenuation that accompanies as a sign of the cerebral infarction [4].

The function of Wiener filtering is eliminating the blurring of the image that is due to unfocussed optics or linear motion. In a study conducted by Khireddine, Benmahammed, and Puech (2007), it is found that Wiener filter is optimum for restoration among the linear filters with noise present on the image [5].

Mean filtering or averaging filter can be a useful tool in removing noise from diagnostic images. Saeidi et al. (2005) proposed a new adaptive weighted averaging filter that is experimentally proven to be effective in preserving the structures and edges of the image and suppressing noise. The proposed averaging filter differs from the current averaging filter in terms of it does not depends on noise variance and only involves the utilization of pixels intensity in noise suppression [6].

The smoothing of filtered image results in blurring of the image details and thus decreases the image resolution. Therefore, in order to overcome this, the image is enhanced by using histogram equalization. In a project conducted by Yan, Ibrahim and Nicholas (2008), histogram equalization are among the three simplest methods that is used to adjust the intensity inhomogeneity in MRI images [7]. The use of histogram equalization results in clearer details and brighter output images [7]. According to Yan, Ibrahim and Nicholas (2008), histogram equalization is useful in adjusting and modifying the image gray level based on the averaging histogram of the series of the MRI input although it was not the best option to completely solve the problem of intensity inhomogeneity in MRI [7].

According to Banerjee and Maji (2013), homogenous unsharp masking is one of the most popular filtering methods that are used to overcome the common problems in MR images that are intensity inhomogeneity [8]. In a study done by Deng (2011), unsharp masking algorithm is used to solve three issues that are contrast and sharpness enhancement, halo effect reduction and out-of-range problem solving by log-ratio and tangent operations [9].

III. METHODOLOGY

1. NOISE REMOVAL

A. Adaptive filtering with unsharp masking

Adaptive filtering also known as a self-modifying digital filter due to its capability to adjust the coefficients time by time in order to match with the characteristics of the desired system [10]. The wiener2 function to an image adaptively, tailoring itself to the local image variance. This method can achieve the desired value of image without the noise but the image become smooth and appears the blurred image.

So, the unsharp masking must be applied after the filtering of the noise in order to improve the blurry image. It can sharpen the edges of the regions or structures related to the affected area. The term ‘unsharp’ itself represent the function to produce the negative image by create a mask to the original image. Combination with the negative image may reduce the blurry of the image.

B. Replicate Wiener filtering with averaging filtering

The wiener filtering is a type of filtering that help to decrease the noise that arises from constant power additive noise. In this case of CT image filtered using pixelwise, neighbourhood 5-by-5 to estimate the local image mean and standard deviation based on the equation as below:

$$\mu = \frac{1}{NM} \sum_{n_1, n_2 \in n} \alpha(n_1, n_2)$$

And

$$\delta^2 = \frac{1}{NM} \sum_{n^1, n_2 \in n} \alpha^2(n_1 \;\; , n_2 \;\;) - \mu^2$$

where n is the N-by-M local neighborhood of each pixel in the image A. wiener2 then creates a pixelwise Wiener filter using these estimates,

$$b(n_1, n_2 \;\;) = \mu + \frac{\delta^2 - v^2}{\delta^2}((a(n_1, n_2) - \mu)$$

where v2 is the noise variance. If the noise variance is not given, wiener2 uses the average of all the local estimated variances.

To enhance and sharp that had undergo the noise removal, the image will be enhance which it contrast of the grayscale image I by transforming the values using contrast-limited adaptive histogram equalization [11].

2. IMAGE ENHANCEMENT

C. Negative transformation

Firstly, the image will be converted from RGB into gray image using the command “rgb2gray”. Next, the MRI original image are T1-weighted image undergo one of the Graylevel transformation using the negative command “j=255-I”. Furthermore, using adjust control tool is an interactive contrast and brightness adjustment tool, shown in the following figure, that can be used to adjust the black-to-white mapping used to display the image [11].

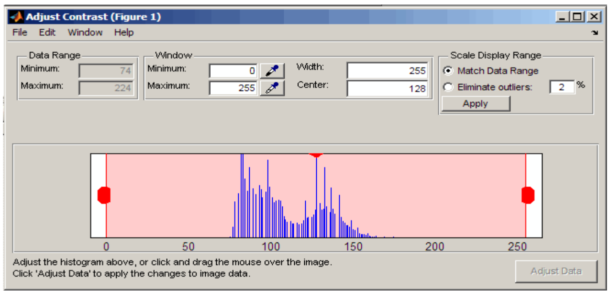

Figure 1 : The contrast and brightness adjustment control tool

D. Adaptive histogram equalisation and unsharp masking

First, the non-contrast T1-weighted image of MRI brain is filtered by averaging filter. This linear filter produces smoothing of sharp features in an image. Thus this reduces the intensity disparity of pixels whose intensities are much above or below those of the neighbors. Though average filter is being outperformed by median filtering in removing salt-and-pepper noise, this filter removes high spatial frequencies from an image and performs well on Gaussian noise. Besides, the application of averaging filter is common in reducing the graininess of an image. This is because as each pixel gets set to the average of the pixels in its neighborhood, local variations caused by grain noise are reduced. However, as mentioned previously, despite reducing noise in an image, averaging filter results in smoothing of the image or which means the removal or reduction in details and resolution of the image and hence, image blurring occur [6].

The MRI image was then enhanced by using Contrast-limited adaptive histogram equalization (CLAHE) or histogram equalization. Histogram equalization is a technique which produces histogram of the resultant image as flat as possible; while stretching the overall shape of the histogram remains the same [12]. It is use when a uniform distribution of the range of values across the full range may not be the appropriate enhancement for certain application, especially if the input range is not uniformly distributed [12]. The contrast is adjusted manually. But as an alternative to using histogram equalization, contrast-limited adaptive histogram equalization (CLAHE) can be performed by using the adapthisteq function. While histeq works on the entire image, adapthisteq operates on small regions in the image, called tiles. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches a specified histogram. After performing the equalization, adapthisteq combines neighboring tiles using bilinear interpolation to eliminate artificially induced boundaries.

Next, to overcome the smoothing effect caused by averaging filter, unsharp masking was used in order to sharpen the image [9]. However there are few drawbacks of this technique, which include excessive contrast images, edges that look like halos around objects, jagged edges, and specked or mottled areas which may happen due to excessive and improper use of its parameters [9].

IV. RESULTS

1. NOISE REMOVAL

A. Adaptive filtering with unsharp masking

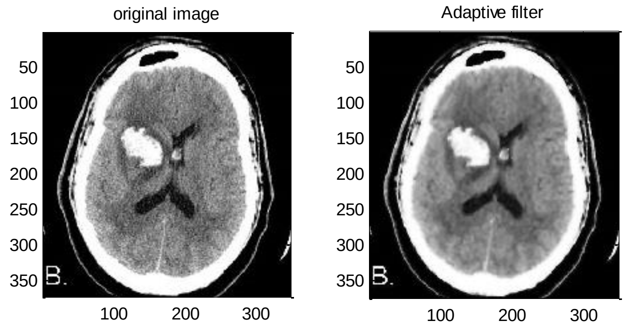

Figure 2: The original image (left side) and the image after using adaptive filtering (right side)

The original image showed the non-contrast head CT scans of stroke patients with intracerebral hemorrhage in the right hemisphere which presenting the leftsided weakness [10]. After adaptive filtering is applied, the smooth image is produced with the slightly blur appearance. The noise in the image has been reduced without sacrifice the details of the affected area in the brain. However, the edges of the intracerebral hemorrhage, anterior and posterior horn of the lateral ventricle are seen not sharp as compared with the original image. So, the image must undergo sharpened technique by using unsharp masking in order to visualize the edges of the structure mentioned above more clearly and sharper.

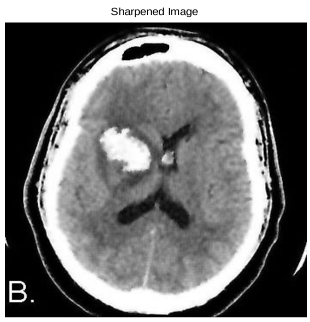

Figure 3: The image after using of unsharp masking

B. Replicate Wiener filtering with averaging filtering

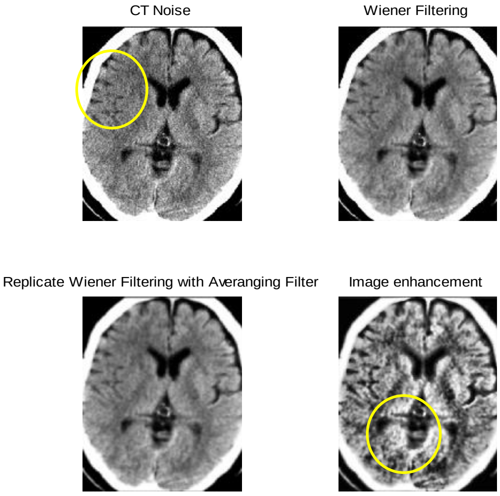

Figure 4: The process of Wiener filtering replicate with averaging filtering and image enhancement

The image using the wiener filtering will cause the output to be almost same as the original image and give out smoothing effect that are depend on the variance which, large variance will results in little smoothing and vice versa with the small variance. Next, by replicate wiener filtering with averaging filtering the image getting much smoothen. Lastly, by enhance the image using contrast-limited adaptive histogram equalization we can see better image. Based on the image (with circle) the right lateral horn of the frontal lobe are narrowing and there is present slightly large dark area if compare with the left side this may indicate the present of hemorrhage which are one of the factors of ischemic stroke.

2. IMAGE ENHANCEMENT

C. Negative transformation

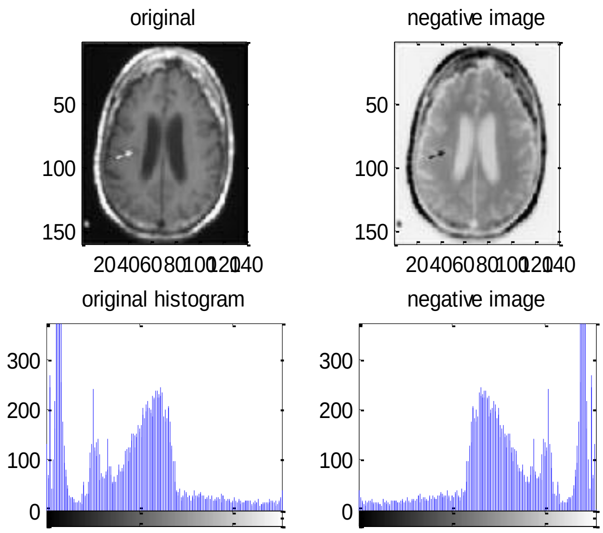

Figure 5: Original image (left side above) and negative enhancement image (right side above)

Figure 6: Original image of T1-weighted image

As can be seen the original image are from the T1-weighted image which the abnormalities (with arrow) appear hypointense and almost invisible to the background contrast. Their histogram also show cluster on the dark side of intensity scale. Using negative processing the histogram has move from the dark into light side of the intensity scale and this shown almost similar image of T2-weighted image as their hypointense region previously become slightly hyperintense on the negative image as above [13]. To make the pathology side more pronounce applying the adjust control tool to the negative image which their brightness and contrast of image can be adjust manually until meet our desired. Subsequently, the final image as above becomes almost as close as the T2-weighted image.

D. Adaptive histogram equilisation and unsharp masking

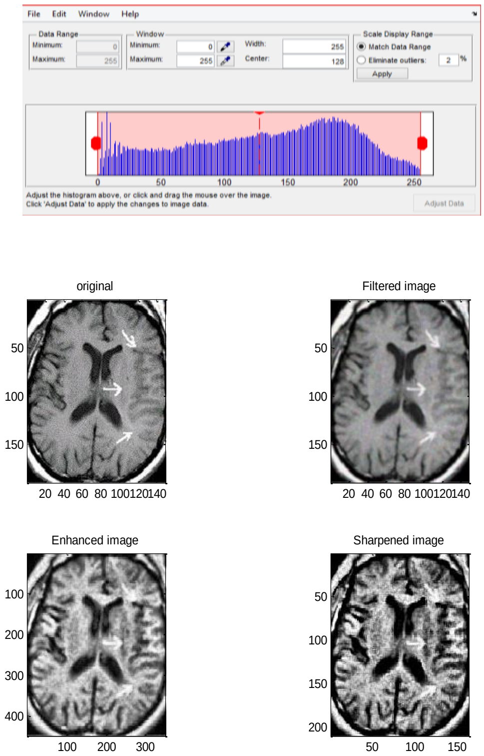

Figure 7: The noise removal and image enhancement of non-contrast T1-weighted image

The original image which is the non-contrast T1-weighted image demonstrates early stroke changes with effacement of cortical sulci in the middle cerebral artery territory associated with swelling and mild hypointensity of the cortical ribbon (arrows). Filtered image appears smooth after being filtered with averaging filter in order to remove noise. Next, the image is enhanced by using adaptive histogram equalization in order to enhance the mild hypointense cortical ribbon area. The image is then being sharpened to remove the smoothing effect by using unsharp mask.

V. CONCLUSION

Based on four original images, there are two main problems that related to the images which the presence of noise and poor contrast images. In removing the noise, there are three methods can be used, adaptive filtering, wiener filtering and averaging filtering. This has been proved by the appearances of the both CT and MRI brain images after filtered are much better from the original images. The filtered image also must undergo sharpened process by using unsharp masking to improve the blurring effect. Besides, to enhance the image, adaptive histogram equalization and negative transformation is used to produce the clearer details and brighter of the output images.

Thus, the process of the digital imaging process must be understand clearly and practiced well in the digital health fields nowadays. This is because, it can improve the quality of the image and reduce the recall rate which can caused harm to the patient.

VI. REFERENCES

[1] Gonzalez, R. and Woods, R. (2010). *Digital image processing*. Upper Saddle River, N.J.: Pearson/Prentice Hall.

[2] Westbrook, C., Roth, C. and Talbot, J. (2011). *MRI in practice*. Chichester, West Sussex: Wiley-Blackwell

[3] Kowalczyk, N. and Mace, J. (2009). *Radiographic pathology for technologists*. St. Louis, Mo.: Mosby Elsevier.

[4] Lee, Y., Takahashi, N., Tsai, D. and Ishii, K. (2007). Adaptive partial median filter for early CT signs of acute cerebral infarction. *Int J CARS*, 2(2), pp.105-115.

[5] A. Khireddine, K. Benmahammed, and W. Puech, “Digital image restoration by Wiener filter in 2D case,” *Adv. Eng. Softw.*, vol. 38, no. 7, pp. 513–516, 2007.

[6] M. Saeidi, S. A. Motamedi, A. Behrad, B. Saeidi, R. Saeidi, R. Saeidi, P. Electrical, and S. Diego, “NOISE REDUCTION OF CONSECUTIVE IMAGES USING A NEW ADAPTIVE WEIGHTED AVERAGING FILTER,” pp. 455–460, 2005.

[7] P. Y. Yan, H. Ibrahim, and S. P. K. Nicholas, “Investigation on several methods to correct the intensity inhomogeneity in magnetic resonance images,” *Proc. 2008 IEEE Conf. Innov. Technol. Intell. Syst. Ind. Appl. CITISIA*, no. July, pp. 55–59, 2008.

[8] A. Banerjee and P. Maji, “Rough set based homogeneous unsharp masking for bias field correction in MRI,” *Lect. Notes Comput. Sci. (including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics)*, vol. 8157 LNCS, no. PART 2, pp. 542–551, 2013.

[9] G. Deng, “A generalized unsharp masking algorithm,” *IEEE Trans. Image Process.*, vol. 20, no. 5, pp. 1249–1261, 2011.

[10] Research.ijcaonline.org. (2016). [online] Available at: http://research.ijcaonline.org/volume97/number15/pxc3897536 [Accessed 30 May. 2016].

[11] Mathworks.com. (2016). *Noise Removal - MATLAB & Simulink*. [online] Available at: http://www.mathworks.com/help/images/noise-removal.html#buh9ylp-72 [Accessed 17 May 2016].

[12] Adam MY, Saeed MM, Ahmed ASA and Technology I (2015) Histogram Equalization in Computational Libraries. *International Journal of Computer Science and Telecommunications* 6(1).

[13] Lansdell, A. (2016). ⚡Presentation "INTRODUCTION TO NEURO MR Dr. Francis Neuffer USC School of Medicine Department of Radiology.". [online] Slideplayer.com. Available at: http://slideplayer.com/slide/3279619/ [Accessed 23 May 2016].

[14] Barnes, E. (2010). *Stroke assessment varies depending on CT perfusion software*. [online] AuntMinnie. Available at: http://Stroke assessment varies depending on CT perfusion software By Eric Barnes, AuntMinnie.com staff writer [Accessed 23 May 2016].

APPENDIX

A. NOISE REMOVAL

ADAPTIVE FILTERING WITH UNSHARP MASKING

```
c=imread('ct1.jpg');
c1=rgb2gray(c);
cw=wiener2(c1,[5,5]);
subplot(1,2,1),subimage(c),title('original image');
subplot(1,2,2),subimage(cw),title('Adaptive filter');
b = imsharpen(cw);
figure, imshow(b)
title('Sharpened Image');
```

REPLICATE WIENER FILTERING WITH AVERAGING FILTERING

```
RGB = imread('1-ConvertImage.jpg');
imshow (RGB);
GRAY=rgb2gray(RGB);
I3 = wiener2(GRAY,[5 5]);
w = fspecial('average',[5 5]);
I4 = imfilter(I3,w,'replicate');
I5 = adapthisteq(I4);
subplot (221),imshow(GRAY);title ('CT Noise');
subplot (222),imshow(I3);title ('Wiener Filtering');
subplot (223),imshow(I4);title ('Replicate Wiener Filtering with Averanging Filter');
subplot (224),imshow(I5);title ('Image enhancement')
```

B. IMAGE ENHANCEMENT

NEGATIVE ENHANCEMENT

```
RGB=imread ('mrit.jpg');
imshow(RGB);
g=rgb2gray(RGB);
g1=255-g;
figure,imshow(g1)
imcontrast (gca)
subplot(2,3,1),subimage(g),title('original');
subplot(2,3,2),subimage(g1),title('negative image');
subplot(2,3,4),imhist(g); title('original histogram');
subplot(2,3,5),imhist(g1); title('histogram equalization');
subplot(2,3,5),imhist(g1); title('negative image');
```

AVERAGE FILTERING AND UNSHARP MASKING

```
I = imread('t1 non.jpg');
% addition of graininess
I_noise = imnoise(I, 'speckle', 0.01);
% create average filter
h = ones(3,3) / 9;
I2 = imfilter(I_noise,h);
imshow(I_noise), title('Original image');
figure, imshow(I2), title('Filtered image');
subplot(121),imshow(I_noise),title('Original image');
subplot(122),imshow(I2),title('Filtered image');
RGB = imread('averagingf.jpg');
GRAY=rgb2gray(RGB);
I5 = adapthisteq(GRAY);
imshow (I5)
imcontrast(gca)
I = imread('histeq.jpg');
J=rgb2gray(I);
K = imsharpen(J);
figure, imshow(K)
title('Sharpened Image');
subplot(2,2,1),subimage(I),title('original');
subplot(2,2,2),subimage(I2),title('Filtered image');
subplot(2,2,3),subimage(I5); title('Enhanced image');
subplot(2,2,4),subimage(O); title('Sharpened image')
```