Effective determination of brain aneurysm by using spatial filtering in MRI and CT images

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Abstract**—Noise can be defines as random dissimilarities of image intensity and appear grainy on the image. It arises on the image due to photon nature or thermal heat effect inside image sensor. Noise usually occurs during image capturing or image transmission. Apart from that, noise consists of number of pixels that have different intensity values rather than true pixel values causing image degradation. Notwithstanding, the application of image processing algorithm aid in reduce noise from the images at highest value. The specific type of noise removal algorithm belongs to the specific type of noise appears on the image. The most common location of aneurysm located at Circle of Willis which is a junction between two carotid and two vertebral arteries. This junction can be developed into a weak spot thus produces outpouching of blood vessels filled with blood. These pouches can leak or rupture and spill blood into surrounding brain tissue. MRI and CT scan is needed for evaluation and diagnosis of aneurysm because these two modalities produce optimum image in showing the growth and location of the aneurysm even the gold standard remain angiography. The methods used to reduce noise are averaging, median and adaptive filter while methods for images enhancement are histogram stretching, histogram equalization and histogram adjustment. The results shows a difference in enhancement and the best filter to reduce the noise is adaptive filter while for the low contrast image, the best method used is histogram adjustment.**

Keywords—brain aneurysm, noise, low contrast, average filter, median filter, adaptive filter, histogram stretching, histogram equalization, histogram adjustment

I. INTRODUCTION

Digital image processing (DIP) represents a contemporary technique and their importance increasing rapidly due to the hasty development associated with computer technology [1]. DIP allows a digital image to be manipulated by using MATLAB command hence produce high quality image for diagnostic purposes. In addition, DIP is used in numerous field of study such as diagnostic medical imaging, space exploration and many others industry. This article enlightens the application of DIP in diagnostic medical imaging field study. The significant advantage of DIP utilization is to enhance the radiographic image for better detection of abnormalities in Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) images of the brain. The objective of this article is to enhance the radiographic images by reducing the noise appearance and adjusting the contrast on the image to acquire more details information resulting good image analysis.

II. LITERATURE REVIEW

Brain aneurysm is basically defined by ballooning of blood in the arteries. The balloon of blood is caused by weakening in artery junctions points of four major blood vessels that joint together at the Circle of Willis at the base of the brain. The aneurysm may rupture or leak and causes bad headache, worse is stroke – like symptoms or the worst is it can cause death. Diagnosis of aneurysm can be done by CT, MRI examinations, lumbar puncture or angiography.

Diagnosis of aneurysm can be done with the aid of MRI and CT scan images. However, the difference in anatomy and physical among human causes the parameter and protocol for MRI and CT scans need to altered in order to compensate the difference. The alteration sometimes can cause the images to have noise or low in contrast. Noise in CT scan comes from the detector itself and the reconstruction kernel. If kernel chosen is sharper, the noisier will be the image. On the contrary, for MRI exam noise is mostly comes from the patient’s body which is radiofrequency (RF) emission caused by thermal motion.

There are various methods that help in reducing or filtering the noise from the images. The averaging filter is the simplest method to minimize noise by minimizes the intensities among adjacent pixels. The concept of this method is to replace the processing pixel value in the matrix of the image with the average value. As a result, it removes the pixel values which are not representing their surroundings. It reads the input image and makes the header information for the output image. It consists of smoothing algorithm and causes the output image as an input for the next iteration. This is if and only if it is not the last iteration and after the completion of all the iterations, the output image is written [6]. The next method is median filter. It is better than the other method because it preserves the edges of the image. This method operates by checking particular pixel whether it representing the nearby neighbors or not and it also replaces the neighbor pixel values. The median filter is calculated by sorting the pixel values into the numerical order. If the center pixel has neighbors which are even numbers, then the two middle pixel values will be used to find their mean and the mean will be used in calculation [6]. Last but not least, the adaptive filter is more preferable than the linear filter because it preserves image edges and image parts which are in high frequency. Moreover, it does not have design tasks because the filter handles all computations and enforce the filter for an input image. This method works best when the image has Gaussian noise [7].

The methods used to enhance the contrast of MRI and CT images are histogram stretching, histogram equalization and histogram adjustment. Histogram stretching is a simple method that improves the image contrast by stretching the range of intensity values to a desired range of values. The method is performed by specify upper and lower pixel value limit from the desired image. It is done without affecting the gray level intensities in a significant way [8]. The next method is histogram equalization. This method is widely used in enhancing the image contrast. The concept is flattens the histogram and stretches the dynamic range in values of intensity by using cumulative density function. Then, transforms the input image histogram by distributes the entire gray level range uniformly over an image histogram with a value of mean which is in the middle of gray level range. It also performs based on the image global content which is the borders and the edges between different objects but it may reduce the details of the objects and causes unequal for local enhancement [9]. The last method for enhancement of image contrast is histogram adjustment. This method improves the image contrast enhanced of histogram equalization that appears dark. In order to brighten or to darken the image, the histogram needs to be adjusted in a new range. This allows the image intensity to be adjusted to a specific or desired range thus a new better image will be produced [10].

III. METHOD

A. *Noise probability density function*

Noise probability density function can be defined as a histogram technique used to determine the types of noise presence on the image [11]. It can be simplified as a noise test is done prior the introduction of different types of filter to correct the image. There are three major steps in order to determine the types of noise. Firstly, extract the noise sample presence at the background of the image. The noise sample from the background is preferable because only one gray level value presence thus prevents reading different gray level value in single histogram. Next, perform the histogram of each noise sample taken by using MATLAB commands. Lastly, refer the noise probability density graph to identify the types of noise based on the shape of the histogram.

B. *Techniques used to filter noise*

Averaging filter also known as mean filter can be described as simple, easy to use and perform smoothing images by minimizing the amount of intensity variance between each pixel. The theory of averaging filter is simply calculates the average value in the selected area. Then, replace the pixel intensity value located at the center with the average value. Finally, repeat the process for all pixels value presented in the image [2]. Averaging filter also described as a convolution filter that is based on a kernel. Frequently a 3x3 square kernel is manipulated, however for severe smoothing might require larger 5x5 square kernels.

Median filter can be elucidate as top sequence static of non-linear filter that functioning based on the sequence of pixel values comprises in the filter area. The theory of median filter is replacing the value of pixel intensity located at the center with the median value of pixel intensity. Concerning median filter, it is best in maintaining sharp edge compared to averaging filter. Besides that, median filter commonly used as image smoothers during image processing and signal processing [2]. Hence it is said to be highly effective for removing salt and pepper noise. Not only that, median filter is beneficial in eliminating the effect of input noise values associated with tremendously substantial magnitudes.

Adaptive filter is a type of linear filter that is used to eliminate noise without markedly blurring the structure of the image [12]. It utilizes an adaptive wiener filter to remove the blurring effect on the images as a result of linear motion. The Wiener filter is preferable when the noise presence on the image is Gaussian noise. It provides a low-pass filter with a frequency element is altered according to the level of noise in the image.

C. *Techniques used to improve contrast*

Histogram stretching is the best way to apply for Gaussian or near-Gaussian histograms where all the values of brightness are within a narrow range of the histogram [10]. The method is done by stretching the original range of intensity value to the suitable range. The technique assigns the original minimum and maximum values of the data brightness extracted from the histogram [13]. Then, a transformation is applied to uniformly stretch the range in order to fill the available brightness values. Thus, the information on differentiation between objects and background is enhanced.

The histogram equalization lacks the distribution of density of the image and as a result, it enhances the image contrast due to histogram equalization has an effect on stretching dynamic range [14]. It will stretch the data from the center and right side to the left side causes the image to appear slightly darker than the original image. However, histogram equalization usually results in excessive contrast enhancement thus it will give the image unnatural look and it can also create visual artifacts. Two dimensional pixel arrays represent the digital images. At a given point, each pixel represents the brightness levels over the whole brightness scale.

The limitation of histogram equalization causes the third technique which is the evolution of histogram adjustment [16]. Image contrast enhanced by histogram equalization will appear dark although the image contrast in improved. In order to brighten or to darken the image, the histogram needs to be adjusted in a new range [16]. This allows the image intensity to be adjusted to a specific or desired range thus a new better image will be produced.

IV. CASE IMAGES

A. *MRI Brain*

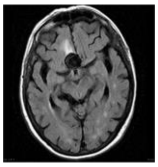


Fig 1. Low contrast of T1W image

Fig 1 is T1 weighted image in axial view of the brain with aneurysm at frontal lobe of the brain. The image is low contrast with no presence of noise. From the image, most of the brain anatomies in the image appear abnormal because of the growth of aneurysm. For each anatomy represent one tone of color; the white matter represent medium grey, the ventricles that contain CSF represent dark and fat represent white.

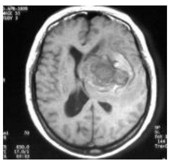


Fig 1. Noisy of T1W image

Fig 2 is the T1 weighted image in axial view of the brain. The image is very noisy surrounded the brain. However, the background of the image is free from noise. Apart from that, the anatomy of the brain and the aneurysm difficult to visualized due to the noise presence. From the image, most of the brain anatomy presence on the image is the combinations of gray level except for the ventricles that contain CSF represent white and the cranial bone represent dark.

B. *CT Brain*

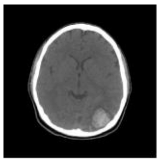


Fig 3. Low contrast of CT image

Fig 3 is CT scan image in axial view of the brain. The image is low contrast because most of the brain anatomies cannot be seen from the image. From the image, most of the brain anatomy presence on the image is the combinations of gray level except for the ventricles that contain CSF represent dark and the cranial bone represent white.

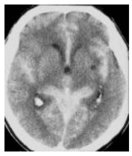


Fig 4. Noisy of CT image

Fig 4 is the CT scan image in axial view of the brain. The image is very noisy because the noise is seen surrounded most of the brain parts thus most of the brain anatomies are obscured. Apart from that, the aneurysm in this brain image also hardly to be identified because of the enormous noise. Most of the brain anatomy presence on the image is the combinations of gray and white spots level except for the ventricles that contain CSF represent dark and the cranial bone represent white**.**

V. RESULT

A. *Noise Identification*

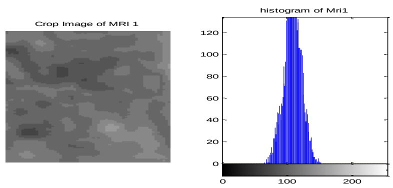


Fig 5. Histogram of low contrast T1W image

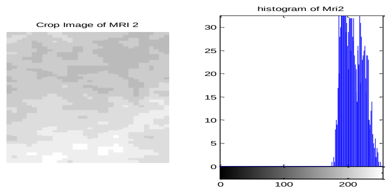


Fig 6. Histogram of noisy T1W image

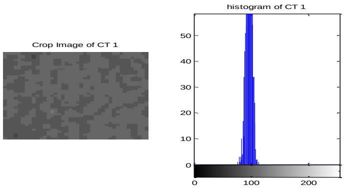


Fig 7. Histogram of low contrast CT image

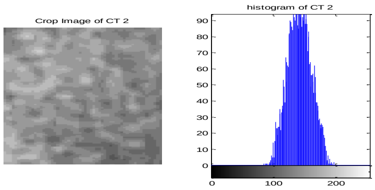


Fig 8. Histogram of noisy CT image

B. *Noise Filtration*

1) Averaging Filter

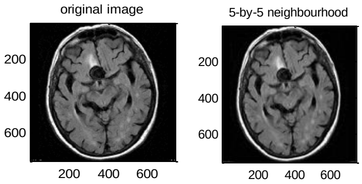


Fig 9. Mean filter of low contrast T1W image (right)

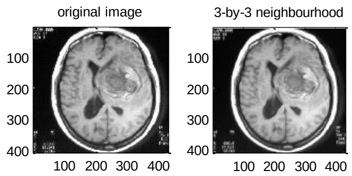


Fig 10. Mean filter of noisy T1W image (right)

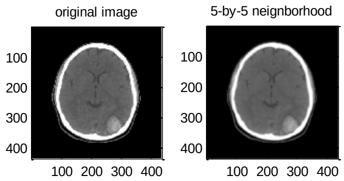


Fig 11. Mean filter of low contrast CT image (right)

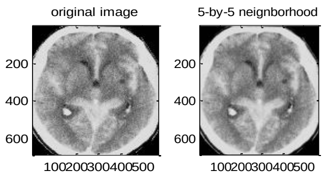


Fig 12. Mean filter of noisy CT image (right)

2) Median Filter

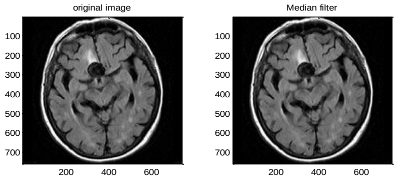


Fig 13. Median filter of low contrast T1W image (right)

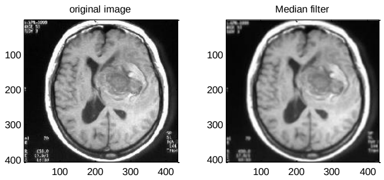


Fig 14. Median filter of noisy T1W image (right)

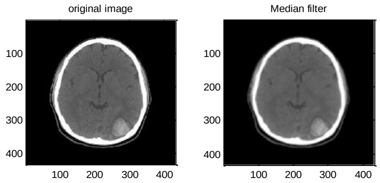


Fig 15. Median filter of low contrast CT image (right)

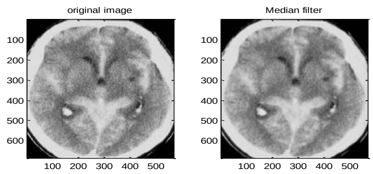


Fig 16. Median filter of noisy CT image (right)

3) Adaptive Filter

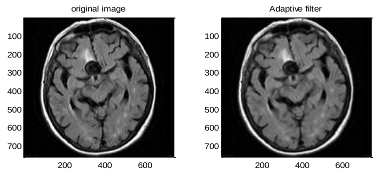


Fig 17. Adaptive filter of low contrast T1W image (right)

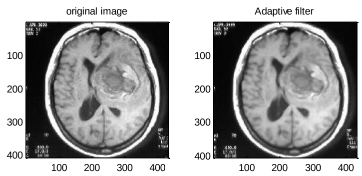


Fig 18. Adaptive filter of noisy T1W image (right)

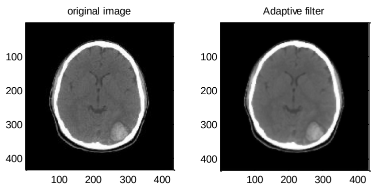


Fig 19. Adaptive filter of low contrast CT image (right)

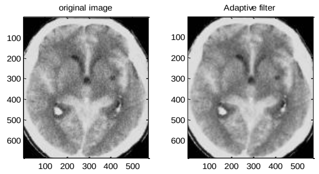
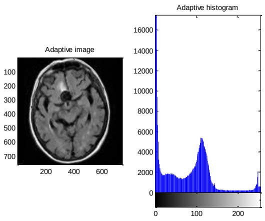


Fig 20. Adaptive filter of noisy of CT (right)

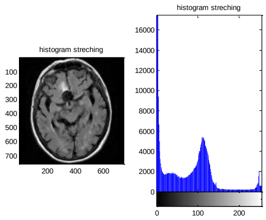
C. *Contrast Enhancement*

TABLE 1: LOW CONTRAST OF T1W IMAGE CONTRAST ENHANCEMENT

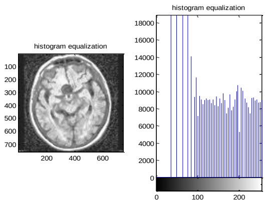
Adaptive image



Histogram streching



Histogram equalization



Histogram adjustment

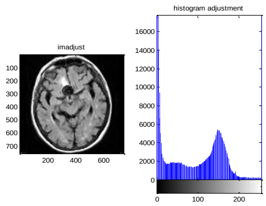
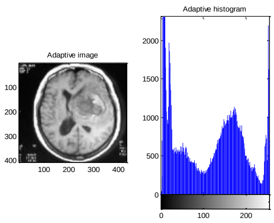
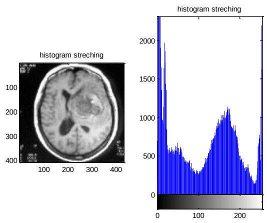


TABLE 2: NOISY OF T1W IMAGE CONTRAST ENHANCEMENT

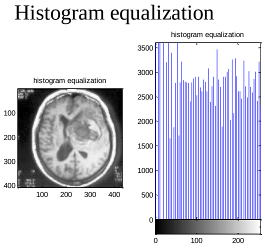
Adaptive image



Histogram stretching



Histogram equalization



Histogram adjustment

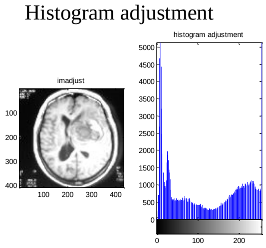
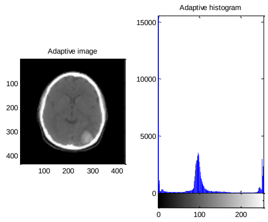
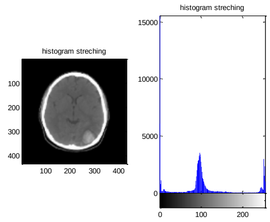


TABLE 3: LOW CONTRAST OF CT IMAGE CONTRAST ENHANCEMENT

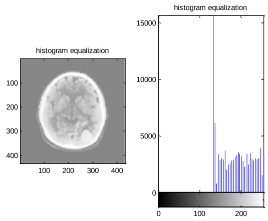
Adaptive image



Histogram stretching



Histogram equalization



Histogram adjustment

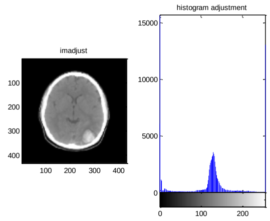
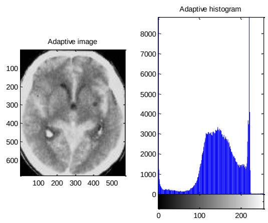
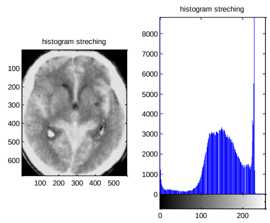


TABLE 4: NOISY OF CT IMAGE CONTRAST ENHANCEMENT

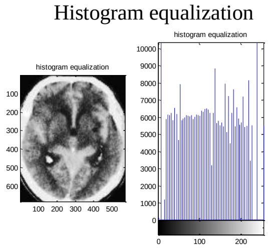
Adaptive image



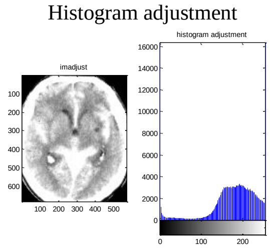
Histogram stretching



Histogram equalization



Histogram adjustment



Based on the result, only one type of noise present in four different images which is Gaussian noise. The type of noise is determined by using noise probability density function [7]. Gaussian noise is best reduced by using an adaptive filter even it can cause blurred to the image. As more noise is reduced, more blur image appeared [12].

From the result obtained, adaptive filter is suitable for T1W MRI images to reduce the noise. This is because the adaptive filter image is smoother, as compared to median filter. Thus, the image of adaptive filter gives better resolution and well pathology defined by the three different filter images [7]. Besides that, adaptive filter also suitable for CT images to reduce noise presence and the scalp of the brain appear more sharper compared to original and median filter image. Therefore, adaptive filter is said to be superior in reducing Gaussian noise in order to clearly visualize the aneurysm on MRI and CT scan brain images.

Then, the output image of the adaptive filter is used for the contrast enhancement. The result shows histogram adjustment is suitable for low contrast images. By using histogram adjustment, the intensity of the image to be adjusted to a new specified range [16]. It increases the contrast of the image by mapping the values of the input intensity image to new values such that, by default, 1% of the data is saturated at low and high intensities [18]. Histogram adjustment image shows the brighter image and smoother contrast through the image. Meanwhile, histogram stretching is preferable for noisy MRI image. This is because histogram stretching involves identifying minimum and maximum brightness values from the histogram and applying a uniform stretch this range to fill the gray values [10]. This enhances the contrast in the image with lightly-toned areas appearing lighter and dark areas appearing darker, differentiating pathology and the background more effectively. Last but not least, histogram equalization is preferable for noisy CT image because uniform distribution of intensities in histogram increases the image into high-resolution and more details appear [14]. Moreover, histogram equalization shows a uniform distribution of the range of values across the gray values [15].

VI. CONCLUSION

Digital imaging processing is a technique to perform processes and manipulate the digital image which can improve the images by enhancing or extract the information. This method has broadly used in medical imaging equipment. The benefit using digital imaging processing is to provide more information in diagnostic pathology and medical health. Moreover, digital imaging can be selected and adjusted to change the characteristics of the images to improve the image quality and optimize the image contrast characteristics thus avoid repeated procedure. Mostly, digital tools such as MRI and CT scan applied the specific algorithm for all kind filters.

VII. REFERENCES

[1] G. Eason, B. Noble, and I. N. Sneddon, "On Certain Integrals of Lipschitz-Hankel Type Involving Products of Bessel Functions," *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences*, vol. 247, pp. 529-551, April 1955.

[2] Maxwell and J. Clerk, "A treatise on electricity and magnetism," *Electricity, Magnetism, Electricity, Magnetics*, vol. 1, p. 504, 1873.

[3] B. Wedro. (2016, 28 May). *Brain Aneurysm (Cerebral Aneurysm)*. Available: http://www.medicinenet.com/brain_aneurysm/article.htm

[4] K. M. Hanson, "Noise and computed contrast discrimination in tomography," *Radiology of the Skull and Brain*, vol. 5, 1981.

[5] M. F. McNitt-Gray, "Tradeoffs in CT Image Quality and Dose " 2002.

[6] H. P. Singh, A. Nigam, A. K. Gautam, A. Bhardwaj, and N. Singh, "Noise Reduction in Images using Enhanced Average Filter," *International Journal of Computer Applications*, 2012.

[7] Mathworks. (1994, 28 May). *Noise Removal*. Available: http://www.mathworks.com/help/images/noise-removal.html#buh9ylp-72

[8] R. Fisher, S. Perkins, A. Walker, and E. Wolfart. (2003). *Contrast Stretching*. Available: http://homepages.inf.ed.ac.uk/rbf/HIPR2/stretch.htm

[9] A. S. Krishna, G. S. Rao, and M. Sravya, "Contrast Enhancement Techniques Using Histogram Equalization Methods On Color Images With Poor Lightning," *International Journal of Computer Science, Engineering and Applications* vol. 3, 2013.

[10] K. A. Zaklika, M. I. Trifonov, and O. V. Sharonova, "HISTOGRAM ADJUSTMENT FEATURES FOR USE IN IMAGING TECHNOLOGIES," *United States Patent*, 2006.

[11] I. S. Jacobs and C. P. Bean, *Fine particles, thin films and exchange anisotropy*. New York: Schenectady, New York : Research Information Section, The knolls, 1963.

[12] K. Elissa, "Title," unpublished|.

[13] J. S. Klein, "Assessing Past Performance and Improving Quality in RadioGraphics: Editor's Page," *RadioGraphics*, vol. 35, pp. 1-5, 2015/01/01 2015.

[14] E. Jefrey, Richmond, and B. S. Rai, "APPARATUS AND METHOD FOR HISTOGRAM STRETCHING," *Patent Application Publication*, 2006.

[15] S. Parker and J. K. Ladeji-Osias, "Implementing a Histogram Equalization Algorithm in Reconfigurable Hardware," 2009.

[16] J. Duan, M. Bressan, and C. R. Dance, "HISTOGRAM ADJUSTMENT FOR HIGH DYNAMIC RANGE IMAGE MAPPING " *United States Patent* 2009.

[17] Rafael C. Gonzalez & Richard E. Woods, 2010. *Digital Image Processing* 3rd editio., Upper Saddle River, NewJersey: Pearson Prentice Hall.

[18] Rafael C. Gonzalez & Richard E. Woods, 2010. *Digital Image Processing* 3rd editio., Upper Saddle River, NewJersey: Pearson Prentice Hall.

APPENDIX

A. Noise Identification Commands:

a) Low contrast T1W image

```
[E,rect]=imcrop(a1);
E=imcrop(a1,[159.5 430.5 60 91]);
figure, subplot(1,2,1), imshow(E); title('Crop Image of
MRI 1');
subplot(1,2,2), imhist(E), title('histogram of Mri1');
```

b) Noisy T1W image

```
[F,rect]=imcrop(b1);
[F,rect]=imcrop(b1);
F=imcrop(b1,[316.5 229.5 31 46]);
figure, subplot(1,2,1), imshow(F); title('Crop Image of
MRI 2');
subplot(1,2,2), imhist(F), title('histogram of Mri2');
```

c) Low contrast CT image

```
[G,rect]=imcrop(c1);
G=imcrop(c1,[239.5 173.5 39 38]);
figure, subplot(1,2,1), imshow(G); title('Crop Image of
CT 1');
subplot(1,2,2), imhist(G), title('histogram of CT 1');
```

d) Noisy CT image

```
[H,rect]=imcrop(d1);
H=imcrop(d1,[165.5 245.5 56 86]);
figure, subplot(1,2,1), imshow(H); title('Crop Image of
CT 2');
subplot(1,2,2), imhist(H), title('histogram of CT 2');
```

B. Noise Filtration Commands:

a) Low contrast T1W image

```
%Averaging filter
RGB=imread('mri1.jpg');
[X,map]=rgb2ind(RGB,256);
imwrite(X,map,'mri1.tif');
[xtress,maptrees]=imread('mri1.tif');
xtreesRGB=ind2rgb(xtress,maptrees);
xtreesRBG=im2uint8(xtreesRGB);
imwrite(xtreesRGB,'mri1.tif');
imshow('mri1.tif');
k=imread('mri1.tif');
l=ones(3,3)/9;
k2=imfilter(k,l);
figure,imshow(k);
```

```
title('original image');
figure,imshow(k2); title ('3x3 filter');
m=ones(5,5)/25;
k3=imfilter(k,m);
figure,imshow(k3); title ('5x5 filter');

%Median filter
k=imread('mri1.jpg');
k1=rgb2gray(k);
k2=im2double(k1);
figure,imshow(k)
figure,imshow(k1)
figure,imshow(k2)
imwrite(k2,'mri1.tif');
kb=imread('mri1.tif');
k7=medfilt2(k1);
figure,imshow(k7);

%Adaptive filter
kw=wiener2(k1,[5,5]);
subplot(1,2,1),subimage(k),title('original image');
subplot(1,2,2),subimage(kw),title('Adaptive filter');
```

b) Noisy T1W image

```
%Averaging filter
a=imread('mri2.jpg');
a1=rgb2gray(a);
a2=im2double(a1);
figure,imshow(a)
figure,imshow(a1)
figure,imshow(a2)
imwrite(a2,'mri2.tif');
b=imread('mri2.tif');
j=ones(3,3)/9;
b2=imfilter(b,j);
figure,imshow(b);
title('original image');
figure,imshow(b2); title ('3x3 filter');
o=ones(5,5)/25;
b6=imfilter(b,o);
figure,imshow(b6); title ('5x5 filter');

%Median filter
j=ones(5,5)/25;
b2=imfilter(b,j);
figure,imshow(b);
b7=medfilt2(b2);
subplot(1,2,1),subimage(b),title('original image');
subplot(1,2,2),subimage(b7),title('Median filter');

%Adaptive filter
bw=wiener2(a1,[5,5]);
subplot(1,2,1),subimage(b),title('original image');
subplot(1,2,2),subimage(bw),title('Adaptive filter');
```

c) Low contrast CT image

```
%Averaging filter
c=imread('ct1.jpg');
c1=rgb2gray(c);
c2=im2double(c1);
figure,imshow(c)
figure,imshow(c1)
figure,imshow(c2)
imwrite(c2,'ct1.tif');
d=imread('ct1.tif');
j=ones(3,3)/9;
d2=imfilter(d,j);
figure,imshow(d);
title('original image');
figure,imshow(d2); title ('3x3 filter');
o=ones(5,5)/25;
d6=imfilter(d,o);
figure,imshow(d6); title ('5x5 filter');

%Median filter
j=ones(5,5)/25;
d2=imfilter(d,j);
figure,imshow(d);
d7=medfilt2(d2);
subplot(1,2,1),subimage(d),title('original image');
subplot(1,2,2),subimage(d7),title('Median filter');

%Adaptive filter
cw=wiener2(c1,[5,5]);
subplot(1,2,1),subimage(c),title('original image');
subplot(1,2,2),subimage(cw),title('Adaptive filter');
```

d) Noisy CT image

```
%Averaing filter
f=imread('ct2.jpg');
f1=rgb2gray(f);
f2=im2double(f1);
figure,imshow(f)
figure,imshow(f1)
figure,imshow(f2)
imwrite(f2,'ct2.tif');
g=imread('ct2.tif');
j=ones(3,3)/9;
g2=imfilter(g,j);
figure,imshow(g);
title('original image');
figure,imshow(g2); title ('3x3 filter');
o=ones(5,5)/25;
g6=imfilter(g,o);
figure,imshow(g6); title ('5x5 filter');

%Median filter
j=ones(5,5)/25;
```

```
g2=imfilter(g,j);
figure,imshow(g2);
g7=medfilt2(g2);
figure,imshow(g7);
subplot(1,2,1),subimage(g),title('original image');
subplot(1,2,2),subimage(g7),title('Median filter');

%Adaptive filter
fw=wiener2(f1,[5,5]);
subplot(1,2,1),subimage(f),title('original image');
subplot(1,2,2),subimage(fw),title('Adaptive filter');
```

C. **Contrast Enhancement Commands:**

a) Low contrast T1W image

```
k=imread('mri1.jpg');
k1=rgb2gray(k);
k2=im2double(k1);
figure,imshow(k)
figure,imshow(k1)
figure,imshow(k2)
imwrite(k2,'mri1.tif');
kb=imread('mri1.tif');
kw=wiener2(k1,[5,5]);
figure;imhist(kw);

%Histogram stretching
kw3 = double(kw);
a_min = min(kw3(:));
a_max = max(kw3(:));
kw4 = 255*(kw3-a_min)/(a_max-a_min);
figure,imshow(kw4)
kw4 = uint8(kw4);
figure,imshow(kw4);
figure,imhist(kw4);
subplot(1,2,1),subimage(kw4),title('histogram
streching');
subplot(1,2,2),imhist(kw4),title('histogram streching');

%Histogram equalization
kw2=histeq(kw);
subplot(1,2,1),subimage(kw2),title('histogram
equalization');
subplot(1,2,2),imhist(kw2),title('histogram
equalization');

%Histogram adjustment
kw1=imadjust(kw,[0 0.75],[0 1]);
subplot(1,2,1),subimage(kw1),title('imadjust');
subplot(1,2,2),imhist(kw1),title('histogram
adjustment');
```

b) Noisy T1W image

```
a=imread('mri2.jpg');
a1=rgb2gray(a);
a2=im2double(a1);
figure,imshow(a)
figure,imshow(a1)
figure,imshow(a2)
imwrite(a2,'mri2.tif');
b=imread('mri2.tif');
bw=wiener2(a1,[5,5]);
subplot(1,2,1),subimage(b),title('original image');
subplot(1,2,2),subimage(bw),title('Adaptive filter');
figure;imhist(bw);
subplot(1,2,1),subimage(bw),title('Adaptive image');
subplot(1,2,2),imhist(bw),title('Adaptive histogram');

%Histogram stretching
bw3 = double(bw);
a_min = min(bw3(:));
a_max = max(bw3(:));
bw4 = 255*(bw3-a_min)/(a_max-a_min);
figure,imshow(bw4)
bw4 = uint8(bw4);
figure,imshow(bw4);
figure,imhist(bw4);
subplot(1,2,1),subimage(bw4),title('histogram streching');
subplot(1,2,2),imhist(bw4),title('histogram streching');

%Histogram adjustment
bw1=imadjust(bw,[0 0.75],[0 1]);
subplot(1,2,1),subimage(bw1),title('imadjust');
subplot(1,2,2),imhist(bw1),title('histogram adjustment');

%Histogram equalization
bw2=histeq(bw);
subplot(1,2,1),subimage(bw2),title('histogram equalization');
subplot(1,2,2),imhist(bw2),title('histogram equalization');
```

c) Low contrast CT image

```
c=imread('ct1.jpg');
c1=rgb2gray(c);
c2=im2double(c1);
figure,imshow(c)
figure,imshow(c1)
figure,imshow(c2)
imwrite(c2,'ct1.tif');
d=imread('ct1.tif');
cw=wiener2(c1,[5,5]);
subplot(1,2,1),subimage(c),title('original image');
subplot(1,2,2),subimage(cw),title('Adaptive filter');
figure;imhist(cw);
subplot(1,2,1),subimage(cw),title('Adaptive image');
subplot(1,2,2),imhist(cw),title('Adaptive histogram');

%Histogram stretching
```

```
cw3 = double(cw);
a_min = min(cw3(:));
a_max = max(cw3(:));
cw4 = 255*(cw3-a_min)/(a_max-a_min);
figure,imshow(cw4)
cw4 = uint8(cw4);
figure,imshow(cw4);
figure,imhist(cw4);
subplot(1,2,1),subimage(cw4),title('histogram streching');
subplot(1,2,2),imhist(cw4),title('histogram streching');

%Histogram adjustment
cw1=imadjust(cw,[0 0.75],[0 1]);
subplot(1,2,1),subimage(cw1),title('imadjust');
subplot(1,2,2),imhist(cw1),title('histogram adjustment');

%Histogram equalization
cw2=histeq(cw);
subplot(1,2,1),subimage(cw2),title('histogram equalization');
subplot(1,2,2),imhist(cw2),title('histogram equalization');
```

d) Noisy CT image

```
f=imread('ct2.jpg');
f1=rgb2gray(f);
f2=im2double(f1);
figure,imshow(f)
figure,imshow(f1)
figure,imshow(f2)
imwrite(f2,'ct2.tif');
g=imread('ct2.tif');
fw=wiener2(f1,[5,5]);
subplot(1,2,1),subimage(f),title('original image');
subplot(1,2,2),subimage(fw),title('Adaptive filter');
figure;imhist(fw);
subplot(1,2,1),subimage(fw),title('Adaptive image');
subplot(1,2,2),imhist(fw),title('Adaptive histogram');

%Histogram adjustment
fw1=imadjust(fw,[0 0.75],[0 1]);
subplot(1,2,1),subimage(fw1),title('imadjust');
subplot(1,2,2),imhist(fw1),title('histogram adjustment');

%Histogram equalization
fw2=histeq(fw);
subplot(1,2,1),subimage(fw2),title('histogram equalization');
subplot(1,2,2),imhist(fw2),title('histogram equalization');

%Histogram stretching
fw3 = double(fw);
a_min = min(fw3(:));
a_max = max(fw3(:));
fw4 = 255*(fw3-a_min)/(a_max-a_min);
figure,imshow(fw4)
fw4 = uint8(fw4);
```

```
figure,imshow(fw4);
figure,imhist(fw4);
subplot(1,2,1),subimage(fw4),title('histogram streching');
subplot(1,2,2),imhist(fw4),title('histogram streching');
```