

The Use of MAX-MIN Filter to Increase Contrast to Noise Ratio (CNR) in Spars Projection Tomography Images

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Abstract

The quality of tomography image reconstruction results is largely determined by the number of projections. If the number of projections is less than the optimum value, artifacts will occur that reduce image quality. One of the image quality parameters is the contrast to noise ratio (CNR). In this study we propose a way to increase CNR using the MAX-MIN filter. This filter works by replacing the intensity of each pixel with the maximum value of the surrounding pixel intensity. After that the same work is repeated but by replacing the pixel intensity with the minimum intensity of the surrounding pixels. The results of the study on the digital Shepp-Logan phantom show that the MAX-MIN Filter can increase the CNR value in all images.

Keywords: Image, tomography, cnr, filtering, noise, artifact

Introduction

Tomography is a method of imaging the interior of an object. Imaging data is obtained from the total value of transmission, emission or reflection by the object from various projection angles [1]. This data is called a sinogram, from which the image can be reconstructed with a certain algorithm, for example back projection. To produce an accurate image, many projection angles are needed, for example every half degree, so 720 projections are needed [2]. To reconstruct an image with many projection angles, it takes a long time and large memory for scanning and data processing. In X-ray tomography for living tissue, the more projections, the greater the radiation dose, which also means the risk of tissue damage and cancer is greater [3-4]. Therefore, it is necessary to propose an algorithm improvement that can produce accurate reconstructed images with a small number of projections.

The number of projection angles greatly determines the quality of the resulting image. If the number of projections is less than the optimum value, artifacts will occur [5-7]. Figure 1 shows the sinogram and the results of the Shepp-Logan phantom reconstruction with different numbers of projections. From Figure 1, we can see the difference in sinogram and reconstructed image for different number of projections. The upper image shows the sinogram and reconstruction results for the number of projections as many as 180 while the lower image shows the sinogram and reconstruction results for the number of projections as many as 45. The image obtained from a few projections will experience defects or noise called artifacts.

According to sampling theory, the reconstruction results will be optimal if the number of projections is almost the same as the number of samples for each projection ($K \approx N$) or more precisely follows the equation [8]:

$$K = \frac{\pi N}{2} \quad (1)$$

where K is the number of projections and N is the number of raysums for each projection. If the number of projections is less than optimum, artifact defects will arise, if the number of projections is greater than optimum, data redundancy will occur, meaning that the greater the number

of projections does not produce an image that is better in proportion to the number of projections. The greater the number of projections, the better the quality of the reconstructed image will be, but after passing the optimum point, the increase in quality is not much as seen in Figure 2.

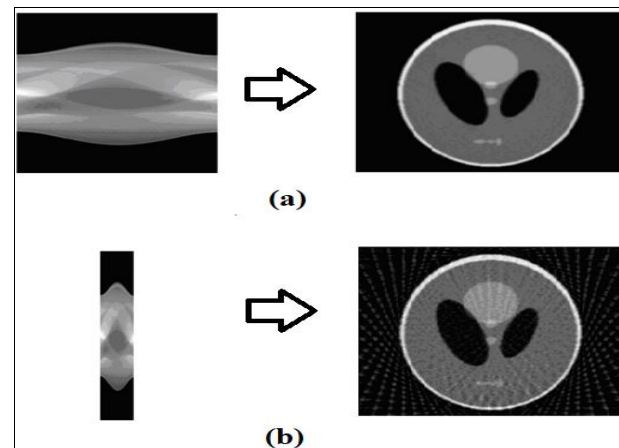


Fig 1: Example of Sinogram and Reconstruction Results of Shepp-Logan Phantom. (a) number of projections as many as 180 (b) number of projections as many as 40

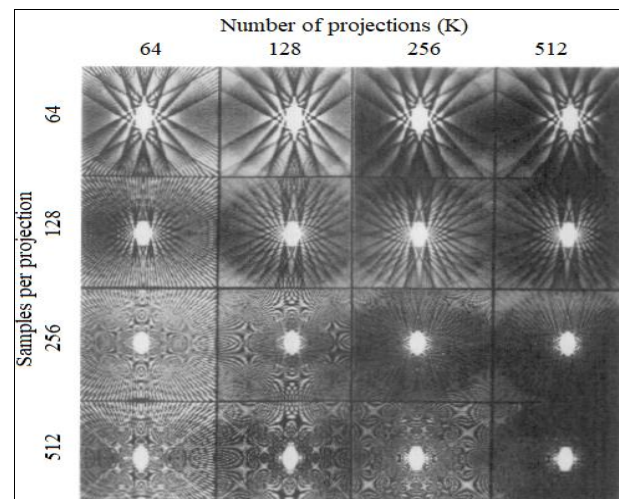


Fig 2: Reconstructed image of an elliptical object with variations in the number of samples per projection and variations in the number of projections [8]

From Figure 2. it can also be seen that the more samples per projection, the better the reconstructed image. The number of samples per projection is called spatial resolution. Low spatial resolution can also cause artifact effects even though the number of projections has passed the optimum value.

Some researchers have applied the Gaussian filter, a convolution operator that can be used to blur images and to remove noise [9]. The Gaussian filter, also known as Gaussian Blur, is an image smoothing filter that uses the Gaussian distribution function to reduce noise and detail in the image. This filter works by multiplying each pixel by a weight calculated based on the Gaussian function which will produce a weighted average of the surrounding pixels. The further a pixel is from the center, the smaller its weight, so that fine details and noise are minimized while larger structures are maintained. The accuracy of estimation with the Gaussian filter method can be applied to various types of applications, but based on our observations, the Gaussian filter is not suitable for application to the results of spars projection reconstruction, because the nature of its noise is not Gaussian

The median filter method is very useful for eliminating poor quality images where most of the pixel intensities have extreme values [10-13]. The median filter arranges the pixel values in one convolution and selects the median value as the result. The median filter is a type of low-pass filter, where this filter works by replacing the pixel values in the original image with the median value of the convolution pixels. Compared to neighborhood averaging, this filter is less sensitive to extreme intensity differences. This filter can be used to remove speckle noise. A better value used to replace a pixel is determined by the median value of each pixel and its eight neighboring pixels. The median filter can be used to remove noise in the image, but it will make the image tend to be blurry, reducing the contrast which results in the CNR not increasing.

The MAX filter in image processing has several advantages, especially in its ability to increase brightness and eliminate point noise (impulse noise) in the image [14]. This filter works by replacing the pixel value with the maximum value of the surrounding pixels in a given window. The maximum filter tends to make bright parts of the image more prominent, because higher pixel intensity values (which indicate brightness) will replace lower pixel intensity values. The maximum filter is effective in removing point-type noise because brighter pixels (from noise) will replace darker pixels around them. In the context of morphology, the maximum filter can be used to expand the boundaries of objects in the image. This means that the object will appear slightly larger after being filtered. With all these properties, the MAX filter is very suitable for increasing the CNR of tomographic images reconstructed from spars projection. In this study, it will also be combined with the MIN filter to increase the SNR.

Method

The research stages consist of image input, filtering with MAX filter, filtering with MIN filter and the end of the stage is CNR measurement. These stages will be explained further as follows:

1. Input Image

The input image is a digital Shepp-Logan phantom from Matlab with a size of 256×256 which is transformed by

Radon as many as 30, 36, 45, 60, 90 and 180 projections, then the inverse Radon transform is performed to obtain 6 reconstructed images. The algorithm for obtaining reconstructed images in Matlab code is as follows:

```
im1=phantom(256);
tetha=180/NUMBER OF PROJECTION
im2=radon(im1,1:tetha:360);
im3=iradon(im2,1:tetha:360);
```

2. Filtering using MAX filter

On each image, the MAX filter process is carried out with a 3×3 kernel. The MAX filter algorithm in the Matlab code is as follows:

im= RECONSTRUCTED IMAGE

```
for i=2:255;
for j=2:255;
p(1)=im(i-1,j-1);
p(2)=im(i-1,j);
p(3)=im(i-1,j+1);
p(4)=im(i,j-1);
p(5)=im(i,j);
p(6)=im(i,j+1);
p(7)=im(i+1,j-1);
p(8)=im(i+1,j);
p(9)=im(i+1,j+1);
p2=max(p);
im2(i,j)=p2;
endfor;
endfor;
```

3. Filtering using MAX filter

On each image, the MAX filter process is carried out with a 3×3 kernel. The MAX filter algorithm in the Matlab code is as follows:

im= IMAGE FILTERING RESULTS WITH MAX FILTER

```
for i=2:255;
for j=2:255;
p(1)=im(i-1,j-1);
p(2)=im(i-1,j);
p(3)=im(i-1,j+1);
p(4)=im(i,j-1);
p(5)=im(i,j);
p(6)=im(i,j+1);
p(7)=im(i+1,j-1);
p(8)=im(i+1,j);
p(9)=im(i+1,j+1);
p2=min(p);
im2(i,j)=p2;
endfor;
endfor;
```

4. CNR Measurement

On each reconstructed image, CNR measurements are performed on the reconstructed image, the MAX filtered image and the MIN filtered image. CNR measurements are performed using two different homogeneous regions, namely region A and region B as shown in Figure 3.

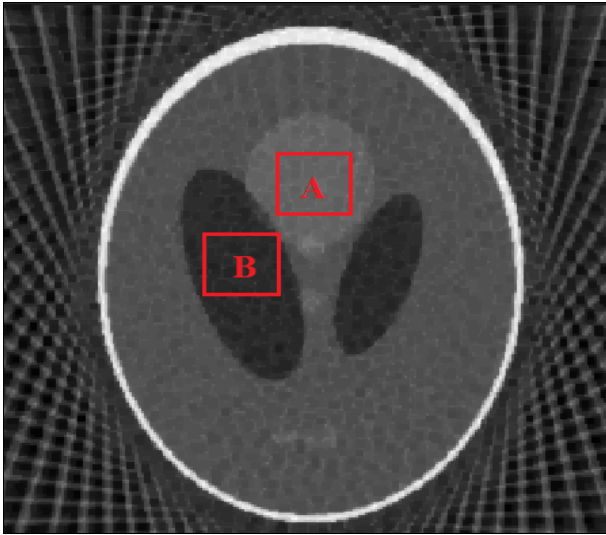


Fig 3: CNR measurement area

The calculation is performed using the ratio equation of the absolute difference of two regions with standard deviation [15-19] as follows:

$$CNR = \frac{|s_1 - s_2|}{\sigma_n} \quad (2)$$

where S_1 is the average intensity in region A, S_2 is the average intensity in region B and σ_n is the average standard deviation in regions A and B. The CNR measurement algorithm in Matlab code is as follows:

```
% imA = crop image region A
imA = imcrop (im3, [120 70 20 20]);
% imB = crop image region B
imB = imcrop (im3, [ 90 40 20 20]);

%area A
im=imA;
jum=0; % the sum of intensity
for i=1:20;
    for j=1:20;
        jum=jum+im (I, j);
    end;
end;
rat=jum/400; % average intensity of each pixel
jumSelKuat=0; % the squared differences
                between the average and
                the intensity of
                each pixel
for i=1:20;
    for j=1:20;
        jumSelKuat=jumSelKuat+
            (im (i, j-rat) ^2);
    end;
end;
ratJSK=jumSelKuat/400; % average of
                jumSelKuat
dev=ratJSK^0.5; % deviation
ratA=rat; %signal region A
devA=dev; % deviation region A

% area B
im=imB;
```

```
jum=0; % the sum of intensity
for i=1:20;
    for j=1:20;
        jum=jum+im (i, j);
    end;
end;
rat=jum/400; % average intensity values eac pixel
jumSelKuat=0; % the squared differences
                between the average and
                the intensity of
                each pixel
for i=1:20;
    for j=1:20;
        jumSelKuat=jumSelKuat+
            (im (i, j-rat) ^2);
    end;
end;
ratJSK=jumSelKuat/400; % average of
                jumSelKuat
dev=ratJSK^0.5; % deviation
ratB=rat; %signal region B
devB=dev; % deviation region B
```

```
%CNR calculation
CNR=abs(ratA-ratB)/(0.5*(devA+devB));
disp (CNR);
```

Result and Discussion

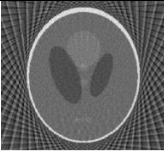

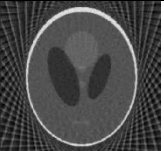
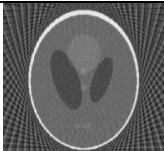
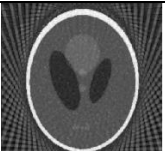
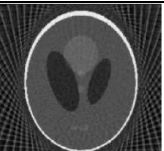
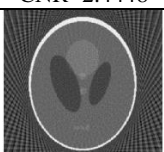
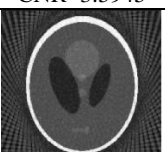
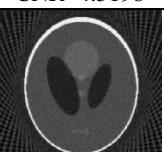
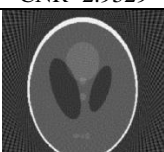

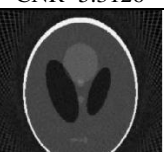
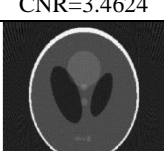
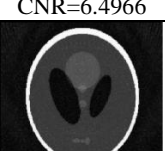
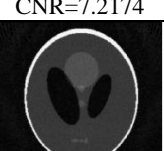
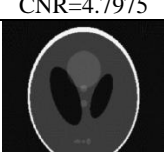
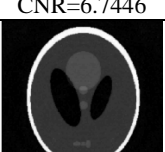
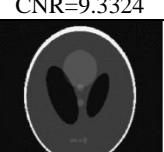
CNR enhancement was performed on 6 images resulting from Shepp-Logan phantom reconstruction with projection counts of 30, 36, 45, 60, 90 and 180. All images went through a filtering stage with MAX Filter and continued with MIN Filter. From the filtering results, we observed the noise changes and calculated the CNR. The measurement results can be seen in Table 1 where the NOP column is the projection count, the REC column is the reconstructed image, the MAX column is the MAX Filter image and the MAX-MIN column is the MAX-MIN Filter image.

From all the experiments that conducted, qualitatively the filtered image experienced noise reduction, both after passing through the MAX Filter and the MAX-MIN Filter. In addition, the dark parts appear darker and the bright parts appear brighter. Quantitatively, from all the experiments conducted, the CNR value of the image increased after going through the filtering process. For more details, the graph of the increase in the CNR value can be seen in Figure 4. From Figure 4, it can be seen that the more projection counts, the higher the CNR, both in the reconstructed image, in the MAX Filter image and in the MAX-MIN Filter image. From Figure 4, it can also be seen that the more projection counts, the greater the increase in CNR.

Conclusion

The CNR of the reconstructed tomography image from spars projection can be increased using MAX-Filter or MAX-MIN Filter. Based on our study, MAX Filter or MAX Filter followed by MIN Filter (MAX-MIN Filter) can increase the CNR of the reconstructed image from Shepp-Logan phantom. The increase in CNR occurs linearly proportional to the number of projections, which means that for images with high CNR, the increase in CNR is also high. The increase in CNR can also be assessed qualitatively by observing visually where the filtered image looks sharper and smoother.

Table 1: CNR measurement results

NOP	REC	MAX	MAX-MIN
30	 CNR=2.2481	 CNR=3.2336	 CNR=3.9969
36	 CNR=2.4448	 CNR=3.5945	 CNR=4.5198
45	 CNR=2.9529	 CNR=3.9947	 CNR=5.3126
60	 CNR=3.4624	 CNR=6.4966	 CNR=7.2174
90	 CNR=4.7975	 CNR=6.7446	 CNR=9.3324
180	 CNR=11.121	 CNR=21.344	 CNR=28.389

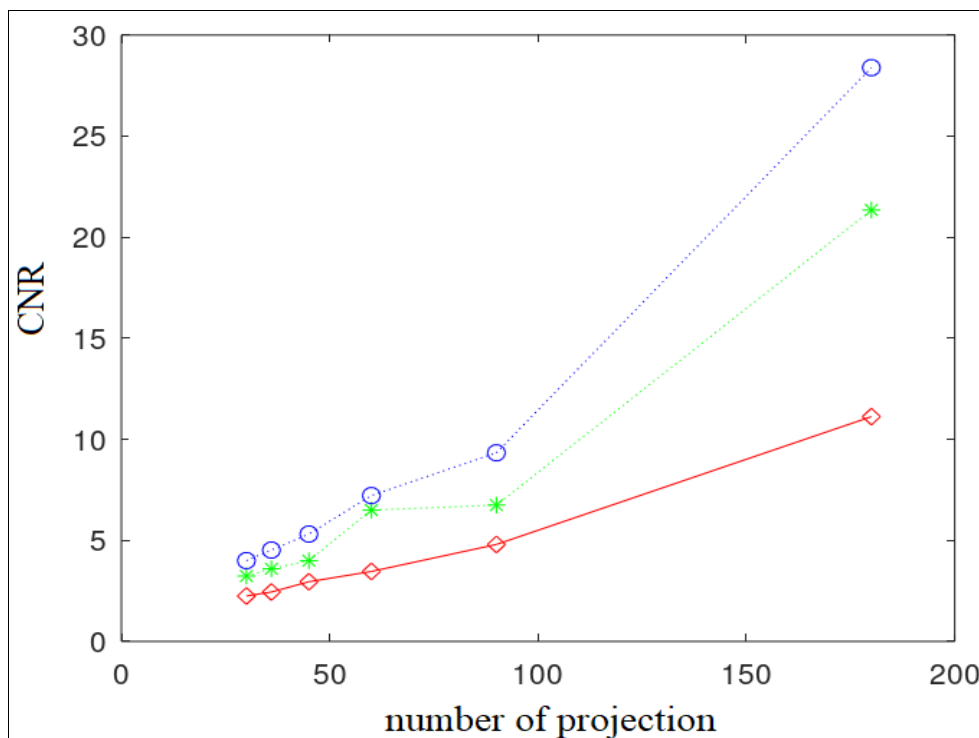


Fig 4: Graph of the relationship between the number of projections and CNR

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