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A Simple Filtering Algorithm for Gamma Spot Removal in Neutron Radiography

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Abstract : In this paper, we report a simple algorithm to reduce gamma spot noise in the neutron radiography image. This algorithm was developed by combining the mean harmonic filter with the adaptive threshold median filter. Tests using a pipe object image and contrast neutron tomography (NTC) object image have been performed. Pipe object and NTC object are measured with the exposure time 4 seconds and 8 seconds respectively. Longer exposure time produces larger density of gamma spot noise. However with this proposed algorithm, noise gamma spot on the test objects can be removed very well and the edges of the object image remain preserved well. For pipe object obtained maximum SNR of 39.2 dB and for NTC object obtained maximum SNR of 24.28 dB can be achieved. The algorithm reported here is very attractive and potential as preprocessing for neutron tomography image.

Key words : Mean harmonic filter, adaptive threshold, gamma spot noise, neutron radiography, neutron tomography, NTC

INTRODUCTION

Imaging with neutron radiography has been widely used for research and non-destructive testing (NDT). Compared with X-rays, neutron has very important role and effectively to investigate the material, especially materials with a low atomic number.

Several techniques for improving image quality of neutron radiography have been developed, such as the improvement of instrumentation systems and measurement methods [1], the installation of brightness enhancement film on the output of scintillator detector [2], the addition of a rotating holder and clamp the object for tomography process [3], the selection of beam energy to obtain monochromatic neutron beam [4] and upgrade the system by adding collimator shielding and improve the ratio L/D [5].

Neutron radiography facility at BATAN utilizes neutron beam generated by RSG-GAS reactor. The techniques of measurement and improvement of quality the neutron radiography system imaging developed by the researchers have been applied to the neutron radiography facility BATAN, including the addition of radiation shielding, controlled rotary table, scintillator screen sensor, mirror reflector, CCD camera and a computer as a control device and data acquisition. Raw image data obtained is a 1024x1024 digital image with 16 bit gray level. The schematic of neutron radiography facilities upgraded shown in Fig 1 [6].

CCD camera is installed on a dark room and surrounded shielding that made of Pb. Shielding is useful to reduce the effects of direct collision between the sensor of CCD camera with gamma particles and neutron scattered. In addition, on the CCD camera is also assembled peltier cooler to reduce the effects of dark current noise. However, although the shielding and cooling perltier have been assembled, gamma spots noise are still visible on the radiographic image.

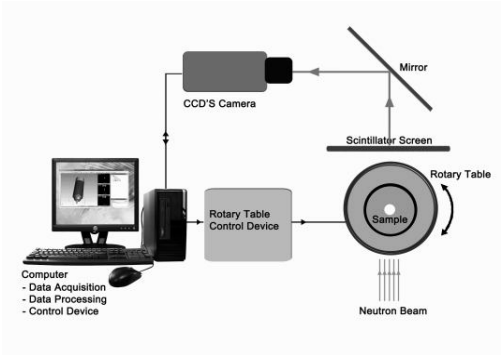


Fig 1. Acquisition device of image neutron radiography

Gamma spot noise on radiography image, if reconstructed into a tomographic image, both two-dimensional and three-dimensional, will be line-shaped artifacts in the spatial domain of image. Therefore, eliminating gamma spot noise is very important in image restoration both neutron radiography and tomography.

To eliminate gamma spot noise, a filter software should be built. The filter software should not change the structure of the image and not reduce the sharpness of the image. Several methods to remove gamma spots noise have been developed. Generally, the filter is presented based on the median filter. Log filter combined with the median filter is developed by [7], this filter can eliminate gamma spot noise, but reduces the sharpness of the image edges. Iterative procedure using glitches and bad pixel algorithm proposed by [8]. This procedure uses a statistical approach and can be used for all types of distorted images. In the use of this procedure must be considered time-consuming, especially for radiographic images, a large number, which will be reconstructed into a tomographic image. Comparison of several filtering methods such as a standard median filter, Z-projection median filter and hybrid PDE filter has been proposed by [9]. It was concluded that the Z-projection median filter with 5 projections gives the best results compared to two other filters. However, for the number of radiographic images will

add a lot of computing time. In addition, the median filter makes the image more blurred.

In this paper, we propose a new algorithm, which is able to retain the object edge detail, to remove gamma spots noise on the neutron radiography image. The method used is a combination of harmonic mean filter and adaptive threshold median filter (MH-ATM). Mean Harmonic filter, that is a non-linear filter, can be used to reduce gaussian noise and salt pepper noise. Mean harmonic filter will be successful to reduce the noise spots that have a higher pixel intensity compared with its neighboring pixels, but will make darker of noise spots pixels that have a lower intensity than its neighboring pixels. The weakness of the mean harmonic filter can be overcome by using adaptive threshold median filter. Radiographic images are filtered by this combined software. The performance of the filter is measured by calculating the signal to noise ratio (SNR).

MATERIALS AND METHODS

System Imaging of Neutron Radiography

Raw image data is taken from neutron radiography installation RSG-GAS BATAN, which operated at 15 Mwatt power. Radiographic equipment data acquisition system is shown in Fig 1. The test object is placed on a rotary table with a resolution of 1° for each step of rotation. Neutrons beam, that transmitted by the test object, is passed through a screen scintillator Li6-ZnS. Screen scintillator serves to change the neutron beam into visible light. Visible light is reflected by the reflector mirror TiO2, with a reflectivity of 95%, and placed in a position of 45 ° to the incident light. Mirror reflector, screen scintillator, and CCD camera are placed in a dark box. To protect the camera from direct collision with scattered neutrons and gamma particles, radiation shield made of Pb and boron carbide (B4C) are installed.

CCD camera from Andor Technology type of icon DD-934N BV, the amount pixels of 1024 x 1024 and pixel size of 13 x 13 μm is used. The camera has Quantum Efficiency (QE) of 95% for the wavelength of 350 -800 nm, high precision and has a 16-bit digitization (gray level 65535). The camera is equipped with Peltier cooling, which is able to reach the freezing level to -100° C. Tamron lens with 50 mm F 1.3 specification, which can set the focus manually, used in this experiment.

To capture the neutron radiography images, CCD camera is connected to a computer. Raw data is recorded in the form of 16-bit gray level image. In this experiment, the piping object and Neutron Tomography Contrast (NTC) [10], which is contaminated by noise gamma spot, are used. Exposure time for the object pipe 4 seconds whereas for NTC 8 seconds.The gamma spots noise are filtered using the proposed algorithm.

Propose Algorithm

Noise gamma spot, which damage the radiographic images, has a wide range of intensity from 0 to 65535, unlike salt and pepper noise that has a discrete value of maximum or minimum intensity. This algorithm uses a detector window 3 by 3, 5 by 5 and 7 by 7, which will detect the presence of noise gamma spot. The example of 3 by 3 windows shown in Fig 2. This window will scan all parts of the image, which has a size of 1024 x 1024 pixels, to detect the presence of noise gamma spots on the image, then calculate the mean harmonics and median value for each step using (1) and (2) respectively [11].

g(p-1,q-1)	g(p,q-1)	g(p+1,q-1)
g(p-1,q)	g(p,q)	g(p+1,q)
g(p-1,q+1)	g(p,q+1)	g(p+1,q+1)

Fig 2: Noise detector window

$$f_h(i,j) = \frac{mn}{\sum_{(p,q)} \frac{1}{g(p,q)}} \quad (1)$$

Where f_h denoted harmonic mean intensity value, i and j denote indices of pixels in the image, m and n denote the length and width of the image, g (p, q) denote the value of the intensity in the window, p and q denote indices of pixels in the window. Equation (1) can eliminate the intensity of the pixels g (p, q) which is higher than the intensity of its neighboring pixels, but will make darker g (p, q) if the intensity is lower than the intensity of its neighbors. To overcome this problem, a local adaptive median filter is used. The median value is used to replace the pixel value is made darker by the harmonic mean filter. The median filter expression as follows:

$$f_{med}(i,j) = median_{(p,q)}(g(p,q)) \quad (2)$$

Where f_{med} is the median value of the pixels in the window. Complete algorithm MH-ATM filter as follows:

1. Subtract the background image on the raw image
2. Find gamma spot noise using window
3. Calculate the value of mean harmonic filter f_h entire pixels in the window.
4. Calculate the median value of the window f_{med} entire pixels in the window.
5. If $f_h < f_{med}$ then g (p, q) = f_{med}
6. If $f_h > f_{med}$ then g (p, q) = f_h.
7. Repeat steps 2 through 6 for the entire image.

This algorithm is repeated for different window sizes. Furthermore, the value of the SNR at a particular image region is calculated.

Analysis of Signal to Noise Ratio (SNR).

To test the success of the denoising process with MH-ATM algorithm, calculation of SNR at the output image is performed. This calculation uses the following equation [12]:

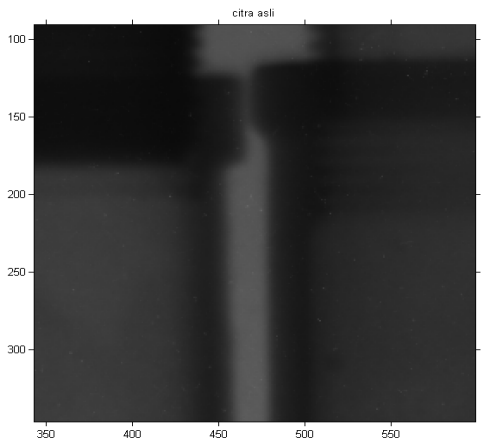
$$SNR = 10 \log \left(\frac{P_s}{P_N}\right) \quad (3)$$

Where P_S denoted average power of the signal, which is obtained by average value of the pixels on the denoised radiographic image. P_N denoted noise power which can be taken as the variance of the particular image region.

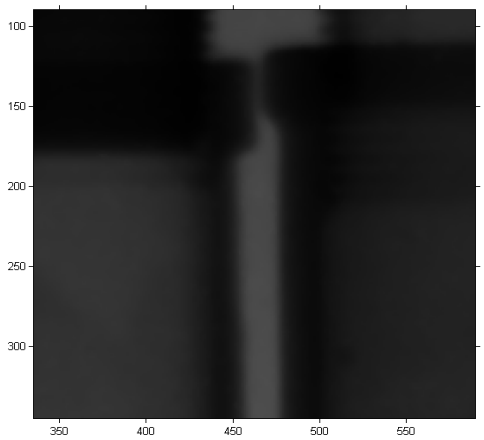
For a large number of radiographic images, SNR values of each image are summed and then divided by the number of images in the analysis to obtain an average value of SNR.

RESULTS AND DISCUSSION

The original image of pipe object, which is sampled, is shown in Fig. 3.(a). This image was taken with the exposure time of 4 seconds. In Fig. 3.(a), it appears some small spots of light. These spots are gamma spot noise, which are caused by the collision of gamma particles with CCD camera sensor. Lower intensity of gamma spot noise compared to its neighboring pixel intensities is not clearly visible. However, if the image is enlarged, the difference in intensity between the pixels will be seen clearly.



(a)

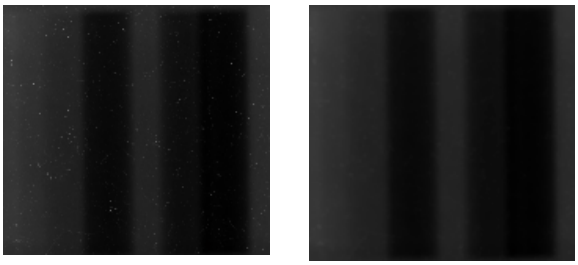


(b)

Fig 3: Neutron radiography image for pipe test object (a) original image, (b) image after denoising process.

In addition, the image of a pipe object is processed using the MH-ATM filter to remove gamma spots noise. In this process, the window size is varied and SNR is calculated. The result of this process is shown in Fig. 3(b) for a window size of 3 by 3. From the fig, it is obtained that gamma spots noise can be removed very well, whereas the edge of object image remains maintained and gray images more uniform.

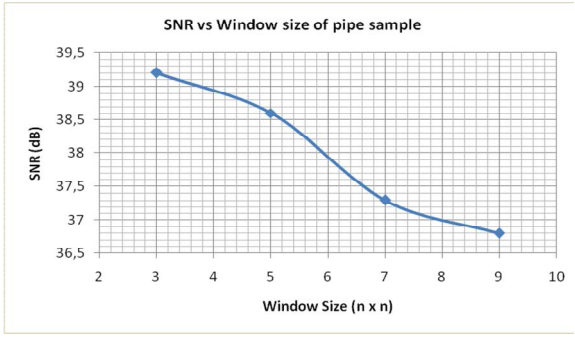
The NTC test object image are shown in Fig. 4. This image was taken with the exposure time of 8 seconds. In Fig. 4.(a), gamma spot noise on the image looks more denser than the image in Fig 3.(a). This was due to exposure time for the NTC longer than the exposure time for the pipe object.



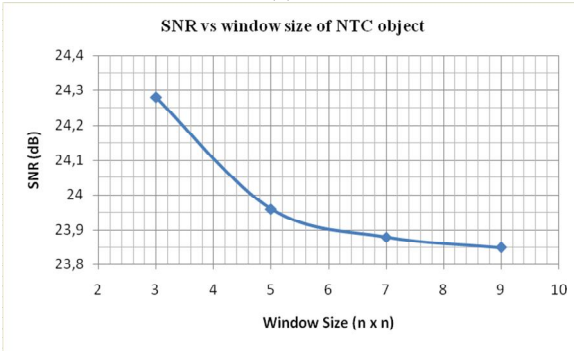
(a) (b)

Fig 4. NTC neutron radiography test object (a) original image, (b) image after denoising process.

Exposure time affects the density of gamma spot noise. The longer exposure time the greater density gamma spot noise. In this image, the intensity of gamma spot noise which is lower than the intensity of neighboring pixels, are also difficult to be seen clearly. The result of the MH-ATM process is shown in Fig. 4.(b). This image is processed with the detector window 3 by 3. It is seen that the gamma spots noise in the NTC image can be removed very well, the edge of object image maintained properly and the distribution of gray image more uniform.



(a)



(b)

Fig 5. Graph SNR versus window size (a) Pipe object, (b) the NTC object.

Success indicators of denoising process, using algorithms MH-ATM, tested by calculating the SNR in certain areas refer to (3). For each window size detector, the SNR is calculated in the same area. The larger the window detector size, the smaller SNR value. In accordance with the characteristics of the harmonic mean filter and median filter, where the larger the window detector makes the output image more blurred. The results of SNR calculation for each window size to changes in the size of the window shown in Fig. 5.

SNR value is influenced by the average of image pixels and standard deviation of the image noise. In other words, the SNR is strongly influenced by the homogeneity of the image, whereas the image homogeneity in neutron radiography influenced by the purity of the neutron beam, wide-narrow energy spectrum of the neutron beam, noise from scattered neutrons and noise from gamma particle. From results of these experiments, the density of the gamma spot noise on NTC image is greater than the pipes image, consequently the SNR values of the NTC image are smaller than the pipe image, as shown in Table 1.

Table 1. SNR value for each window detector.

Window	SNR of pipe objek (dB)	SNR of NTC objek (dB)
3x3	39,2	24,28
5x5	38,6	23,96
7x7	37,3	23,88
9x9	36,8	23,85

Longer exposure time also affects the homogeneity of the radiographic image. If the pipe and NTC image are enlarged, it would seem the uniformity of each image pixel. Visually, radiographic pipe image is more uniform than the radiographic NTC image.

SNR calculation was also performed on a large number of radiographic images for the image number of 5, 10, 50, 100 and 180. In this calculation, denoising using standard median filter and MH-ATM filter are compared. The averages of SNR calculation result are shown in Table 2.

Table 2. Comparison of the average SNR between the standard median filter and MH-ATM filter for a number of radiography images

Number of Images	Average SNR (dB)	
	Median Filter	MH-ATM Filter
5	25,54	29,95
10	24,86	27,78
50	24,20	27,18
100	24,11	27,39
180	24,24	27,54

It appears that the SNR of MH-ATM filter is better than the standard median filter. Average SNR values for any number of different radiographic image are not identical. This indicates that the uniformity of each neutron radiography image is not the same. Neutron radiography images intensity are not uniform due to the instability of the neutron beam flux density generated by the reactor.

The image comparison of the denoising results using median filter and MH-ATM filter for a radiographic image are shown in Fig. 6. The images were taken from the test object of NTC with 4 seconds exposure time. Fig. 6.(a) shows the original radiographic image, fig. 6.(b) shows the denoised image using standard median filter and Fig 6.(c) shows the denoised image using MH-ATM filter. SNR for each image 6. (b) and 6 (c) are 21,35 dB and 24.28 dB respectively.

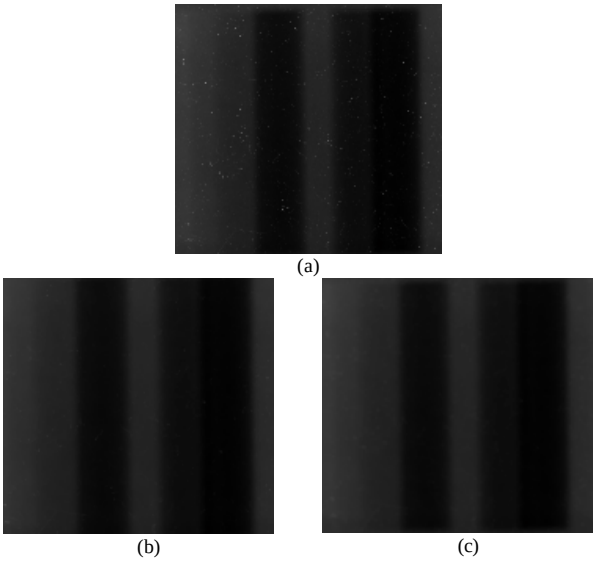


Fig. 6. (a) original image, (b) denoised image using standard median filter (c) denoised image using MH-ATM filter.

Shown in Fig. 6 that the result of MH-ATM filter is better than the standard median filter. Fig. 6 (b), the result of the median filter, still looks spots noise, whereas in Fig 6 (c), which is the result of MH-ATM filter, noise spots have disappeared. The resulting images of MH-ATM filter is smoother and cleaner than the standard median filter.

CONCLUSION

In this paper, the algorithm of MH-ATM filter to remove gamma spots noise on the neutron radiography image has been proposed. The algorithm, simple but powerful, has shown better performance than the standard median filter. In the experiment, the piping and NTC object, which is contaminated by noise gamma spot, are used. On the NTC image, single image and multiple images are used to calculate the SNR and the average of SNR value. The calculation result of the average SNR for multiple images can be used to look at the quality of the neutron beam, which is used as a source of imagery. MH-ATM algorithm gives better SNR than standard median filter. The proposed algorithm is very effective used for gamma spot noise removal on the radiography images and as a preprocessing equipment to obtain the best tomographic images.

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