SNR and PSNR measurements and analysis of median filtering for the removal of impulse noise from CR imaging

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ABSTRACT

In this paper, the authors showed that the removal of impulse noise in CR images was implemented using variety of median filters and SNR/PSNR measurements. They used three kinds of medical images-hand, skull, and knee- for experimental results. But the noise in CR image was only the impulse noise. In real medical image, the noise of an image would be very different type. Therefore, the lack of experimental results using different noise in CR images is one flaw.

Keywords : *SNR, PSNR, CR*

1. INTRODUCTION

Digital medical image has rapidly been improving with the recent development of PACS (Picture archiving and communication system). The recent development of CR (Computed radiography) and DR (Digital radiography) enables X-ray images to be converted into digital images and the digital conversion of the X-ray image has contributed to the rapid spread of PACS system [1], [2]. While CR embodies the digital image using IP (Image plate) that contains a photostimulable fluorescent material instead of films, DR or DDR (Direct digital radiography) expresses the direct digital image of X-ray using Amorphous silicon;a-Si or Amorphous selenium;a-Se [3], [4], [6]. Unlike the conventional film image, accordingly, these improvements characterize the advantages of enabling the examination image to be copied multiple times, preventing possible loss of the image, sharing the image among various departments in the hospital using the picture search system, and reducing film storage space [5], [8], [9]. Therefore, in this study, a Kernel size Median filter was used on each digital image with fixed Impulse noise (salt and pepper noise). Measurements and comparisons were made using SNR and PSNR for each image.

2. RESEARCH BACKGROUNDS

2.1 Structure and function of IP

IP detects X-ray image and is made of a thin and flexible plate having less than 1mm of thickness; halogenated crystals are applied on the support layer made of a high molecular material. The structure of IP consists of a protective layer, a fluorescent layer, a support layer, a backing layer and a barcode

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layer. The protective layer prevents possible damage during handling as well as shrink and damage caused by the temperature or humidity. Barium (BaFX: EU2+) corpuscles (5~10㎛) are sprayed on the fluorescent layer; the support layer which is black and acts as a light absorbing layer to absorb the light generated by halation and irradiation in order to improve the sharpness by reducing fog; the back protective layer protects the surface of IP when IP moves. Figure 1 shows the structure of IP.

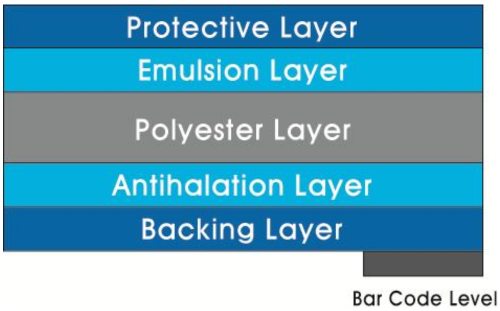


Fig. 1. IP structure

2.2 Advantages and Disadvantages of CR system

CR system uses an image plate on which photostimulable fluorescent material is applied, instead of the conventional films/screens. The image plate is like a film cassette of the film-screen system and it can be used repeatedly for a certain period of time. If X-ray is radiated on the image plate, the latent images are accumulated; when this one is put in the reader and laser beam is radiated, optical signals are generated proportional to the X-ray energy absorbed into fluorescent material. These signals are collected into a condenser guide, are amplified through a photomultiplier tube, and are converted to electric signals; and then the electric signals are converted to digital data through an A/D converter. Accordingly, there are some advantages in this system: first, it is economical because it can replace IP with the cassette while a conventional X-ray generator is used continuously; second, it always enables to get images of a certain quality and reduces the re-scan rate because dynamic range is wider than films/screens and it shows a straight reflection; third, it can reduce radiation exposure. By the way, the amount of the radiation increases noise and lowers the quality of the image; forth, its spatial resolution is high. There are characteristic disadvantages in IP, however: first, there are lots of noises. It occurs because the energy of K absorption edge of the fluorescent material is lower than one of the rare-earth fluorescent material; second, its time resolution is low. It can not get the digital image right after scanning; third, it is difficult to erase images. A few images remain on the fluorescent plate after erasing. Finally, the life span of the photostimulable fluorescent material is short.

2.3 Median filter

Median filter is a filter that calculates and outputs the median of pixel values in a local area from a histogram. When the number of pixels included in the local area is N and the pixel values are arranged in the increasing order, the N-th pixel value out of twelve pixel values becomes the median. Accordingly, it enables to control the flow of the image and to erase it almost completely if salt and pepper noise is included in the image.

2.4 SNR

Precise signal-to-noise ratio is called by signal-to-noise ratio and SNR means a measurement of the quality of signals. The higher the ratio, the better the image is. The measurement method of SNR regards a compressed image f'(x,y) as a signal and an error as a noise. SNR is mainly measured by dB and signal-to-noise ratio is expressed equation (1).

$$SNR = \sqrt{\frac{\sum_{x=0}^{M-1}\sum_{y=0}^{n-1} f'(x,y)^2}{\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}[f'(x,y)-f(x,y)]^2}} \cdots\cdots\cdots (1)$$

f(x,y) : Input Image Value
f'(x,y) : Noise Coordinate Value
f'(x,y) - f(x,y) : Value Difference

2.5 PSNR

PSNR refers to a unit of the measurement of image quality which is most commonly used as an objective valuation standard that measures generally the quality of the image. In both numerical equations (2) and (3), MSE which is a noise term, an abbreviated word of 'Mean squared error', is an average value of square numbers of errors and MAX means the maximum value (because 1byte ranges from 0 to 255, its maximum value is 255) that the pixel can have in the image and i stands for i resolution of the image, j stands for j resolution of the image, I(i,j) stands for the pixel value of the compared image of coordinate (i,j), and K(i,j) stands for the pixel value of the original image of coordinate (i,j).

$$PSNR = 10\cdot\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20\cdot\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \cdots\cdots\cdots (2)$$

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1} \| I(i,j) - K(i,j) \|^2 \cdots\cdots\cdots (3)$$

3. EXPERIMENT DEVICE AND METHOD

3.1 Experiment Device

- General X-ray system : SHIMADZU IR-500-125
- CR(Computed radiography) Digitizer : AGFA Compact plus
- IP(Image plate) : AGFA ADC MD 40 Plate (10 X 12')
- PACS : GE Centricity RA1000
- Phantom : Hand, Head, Knee
- Software: ImageJ, Median filter demo, klPT-build

3.2 Experiment Method

This study used available phantoms such as Hand, Head and Knee to measure SNR and PSNR. The examination of X-ray was conducted under the conditions that the distance between a X-ray tube and IP was 100m and Phantom was placed on the IP.

• Used Voltage, Used Electric Current : Hand- 42Kvp, 8mAs
Skull- 72Kvp, 24mAs
Knee- 50Kvp, 12mAs

3.2.1 Generation of Salt and pepper noise

The images were acquired by generating each of 1%, 3% and 5% of salt and pepper noise on each Hand, Skull and Knee by using the Median filter software (Fig. 2). The acquired images were filtered according to each kernel size using each median filter.

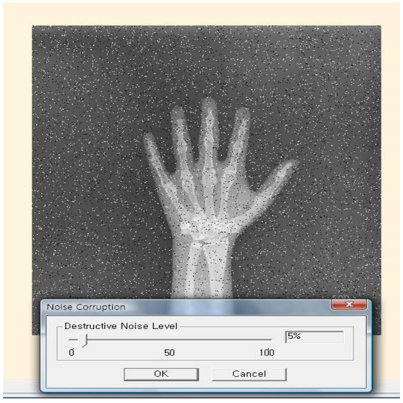


Fig. 2. Salt and pepper noise formation

3.2.2 SNR

SNR was used in comparing the noises of two images and klPT-build is installed as the software. SNR was calculated after filtering and analyzing the original image according to each kernel size, and then its highest value was recognized as the best image value(Fig. 3).

3.2.3 PSNR (Peak signal to noise ratio)

Under the same condition as SNR mentioned above, PSNR of two images was equipped with klPT-build as the software. PSNR was calculated after filtering the image according to each kernel size and analyzing the image, and then its highest value was recognized as the best image value(Fig. 3).

Fig. 3. SNR and PSNR measurements using klPT-build

4. EXPERIMENT RESULT

4.1 Hand

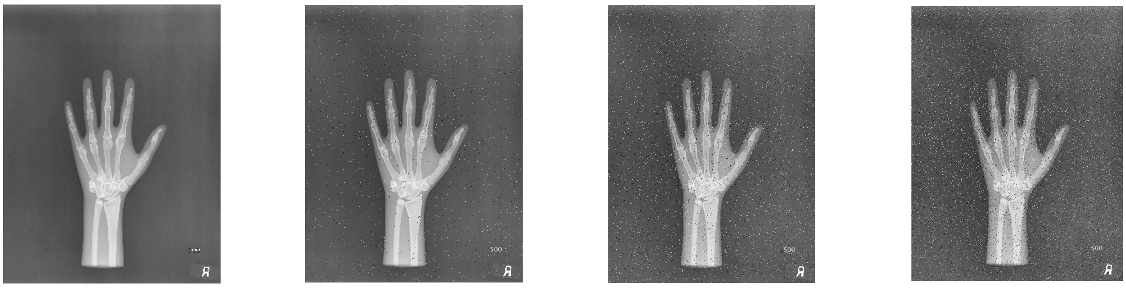
As shown in Figure 4, each of 1%, 3% and 5% of noise value were given to the original image of Hand. In case of SNR, the value was 39.63 when 1% was given to the original image, 32.85 for 3% and 28.82 for 5%. In case of PSNR, the value was 45.12 for 1%, 41.14 for 5% and 36.33 for 5%. According to each noise, SNR values were compared for each noise as shown in Table 1 which shows the result of median filtering with different kernel sizes consisted of 3 X 3, 5 X 5, 7 X 7 and 9 X 9 to the acquired image. The values of kernel size 3 X 3 and 5 X 5 were similar to SNR values of the original image. The values of PSNR increased from 3 X 3 to 5 X 5 and up to 7 X 7 sizes. Both the value of PSNR and the value of SNR decreased in case of 7 X 7 and 9 X 9 sizes.

4.2 Skull

As shown in Figure 5, each of 1%, 3% and 5% of noise value was given to the original image of Skull. When 1% was given to the original image, the value of SNR was 38.72, 33.07 for 3% and 27.61 for 5%. Filtering was conducted to the acquired image of the Skull, wherein different kernel sizes were applied to the image. As shown in the experiment result, the Kernel size of 5X5 and 7X7 were useful to get good values for SNR and the Kernel size 3X3 and 5X5 were useful to get good values for PSNR(Table 2).

4.3 Knee

As shown in Figure 6, each of 1%, 3% and 5% of noise value was given to the original image of knee. When 1% was given to the original image, the value of SNR was 39.88, 33.76 for 3% and 29.59 for 5%. Filtering was conducted to the acquired image of the Knee, wherein different kernel sizes were applied to the image. As shown in the experiment result, the Kernel size of 5X5 and 7X7 were useful to get good values for SNR and the Kernel size 3X3 and 5X5 were useful to get good values for PSNR(Table 3).

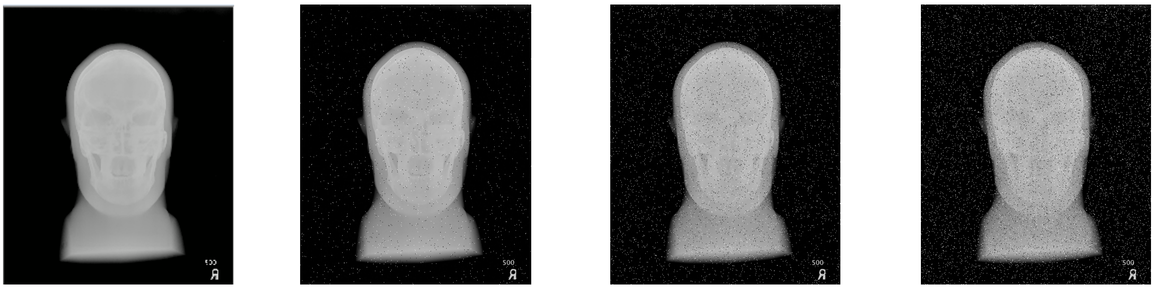


Original image **Noise 1%** **Noise 3%** **Noise 5%**

Fig. 4. Hand noise image

Table 1. Results of hand images using median filtering (Unit : dB)

Noise		Original image compared to SNR & PSNR	3 X 3	5 X 5	7 X 7	9 X 9
SNR	1 %	39.63	35.83	35.05	34.06	33.04
	3 %	32.85	34.56	34.49	33.77	32.87
	5 %	28.82	32.50	33.51	33.26	32.57
PSNR	1 %	45.12	45.12	43.35	42.11	41.14
	3 %	41.14	43.35	43.35	42.11	41.14
	5 %	36.66	40.34	42.11	41.14	40.34

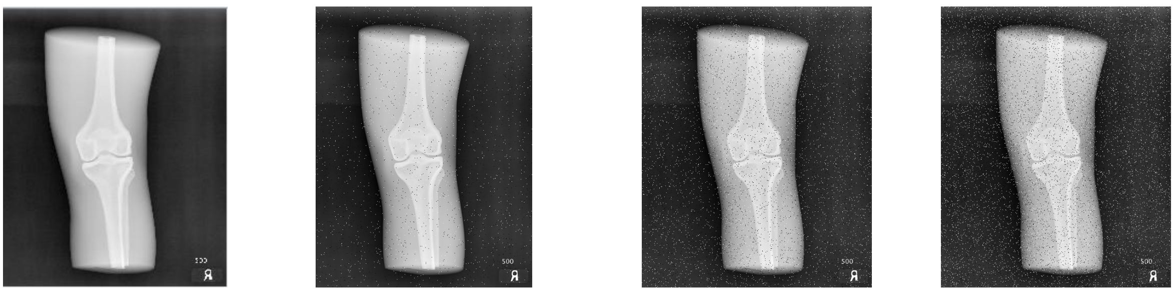


Original image **Noise 1%** **Noise 3%** **Noise 5%**

Fig. 5. Skull noise image

Table 2. Results of Skull image using Median filtering (Unit : dB)

Noise		Original image compared to SNR & PSNR	3 X 3	5 X 5	7 X 7	9 X 9
SNR	1 %	38.72	38.61	37.72	37.13	34.45
	3 %	33.07	33.90	34.03	33.39	32.13
	5 %	27.61	29.06	34.03	29.41	28.90
PSNR	1 %	48.13	48.13	48.13	48.13	43.35
	3 %	42.11	43.35	43.35	42.11	41.14
	5 %	36.36	37.71	43.35	38.13	37.71



Original image **Noise 1%** **Noise 3%** **Noise 5%**

Fig. 6. Knee noise image

Table 3. Results of Knee image using Median filtering (Unit : dB)

Noise		Original image compared to SNR & PSNR	3 X 3 size	5 X 5 size	7 X 7 size	9 X 9 size
SNR	1 %	39.88	39.16	37.39	35.91	34.58
	3 %	33.76	36.30	36.43	35.49	34.37
	5 %	29.59	33.87	35.29	34.92	34.05
PSNR	1 %	48.13	48.13	45.12	43.35	42.11
	3 %	41.14	43.35	43.35	43.35	41.14
	5 %	36.36	41.14	42.11	42.11	41.14

5. CONCLUSION AND FUTURE ASSIGNMENT

In case of digital image, the information passed the object is converted to electric signals and, through analog/digital conversion process, the grey scale value of the pixel is obtained[7], [10], [11]. After the noise or randomicity of the initial data is erased through an appropriate image processing procedure and the processed data is converted into the analog signal in order to be expressed on the films or screen[12][13]. Currently hospitals are much interested in the development of PACS system as well as digital medical image. The digital image, however, can be mixed with noise during the transmission or it can be distorted by other factors of the system. In this case, noise can be reduced and the digital image can be recovered enough to receive the distorted image using a noise filer. In the electrical engineering field, even though LPF(Low pass filtering) is commonly used to erase noise, this filtering is only suitable for the removal of Gaussian filter but it is not suitable for the removal of impulse noise. It is because the distorted image by the impulse noise contains lots of pixels which have obvious brightness values such as 0 or 255. If the loss pass filtering method applies to these signals, neighboring pixels of these signals are affected. If the Kernel size of the filter mask gets larger, the number of pixels affected by these signal is increased. In this case, the Median filtering is efficient to remove the impulse noise[15], [16]. The advantage of this filter is that it preserves the strong edge as well as the conventional edge in details. The possibility of preservation and reinforcement of the detailed edge is important in applying the filtering. In addition, constant change of exposure in the image detector can be displayed by a difference of equal brightness no matter whether it is in a dark side of the image or in a bright side and the reading of a normal or abnormal anatomical structure depends on the visualization of the edge. Transfer between high frequency and low frequency which decides the range of the improved frequency is determined by the Kernel size which is used to smooth the input image. The results from using a Kernel size Median filter are as follows: positive SNR and PSNR results can be obtained in 3x3 and 5x5 hand images; 5x5 skull and knee images; however, for 9x9 images too much filtering will decrease SNR and PSNR results. Instead, it showed that the overused filtering method decreased SNR and PSNR. Even though different Kernel sizes of the filter were applied to each part using these filters, it could not get the better image. Accordingly, it is considered that medical image needs to carry out visual evaluation as well as the comparison by quantitative indexes such SNR, PSNR and MSE. That is because the significance expressed by the visual evaluation is not exactly same with the significance expressed by the quantitative indexes. Actually, visually worse results came out when the filter acquired through the medical image experiment was applied[14], [17]. Because factors (such as voltage, electronic current and exposure time) for the X-ray scan are applied differently according to radiography parts and the different filters are applied by each of medical equipment companies during the image processing, it seems difficult to use the same filter under the different scanning conditions considering different equipment characteristics.

The result of the study shows that the status of a patient’s sickness can be understood differently due to the minute difference of the image in the medical image field even though SNR and PSNR of each image do not show many differences and in the future study, it is necessary not only to learn SNR and PSNR by X-ray scanning parts and factors but also to learn correctively various filtering methods which are used differently in each company as well as to conduct the visual evaluation and the quantitative evaluation on image by the filtering methods applied to each part.

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