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To cite this article: Susilo *et al* 2019 *J. Phys.: Conf. Ser.* **1170** 012076

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Contrast-to-noise ratio and histogram analysis of modified digital radiography image of pet

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Abstract. This work presents the quality analysis of the digital image of pet to obtain optimum exposure factors for pet radiography diagnosis using conventional-modified digital radiography. The digital radiography that used was conventional radiography which was modified by using the digital camera, intensifying screen and image processing software so that it works as digital radiography. The object, a bone-broken cat, was exposed to X-ray radiation from the digital radiography with various exposure factors which are voltage, current and exposure time. The image quality analysis was done by performing Contrast-to-Noise Ratio (CNR) analysis and histogram analysis using image processing toolbox provided by MATLAB. The results show that exposure factors of the voltage of 60 kV, the current of 16 mA and exposure time of 0.20 s provided CNR highest value which is 57.249. Histogram analysis shows that the image with the above-mentioned exposure factors has almost uniform grey intensity distribution. □

1. Introduction

X-ray Radiography has been widely used for the diagnosis of human disease for decades. In line with the fast development of digital technology, digital radiography has replaced the use of conventional radiography. The utility of digital radiography provides many benefits such as environmentally friendly since it no longer uses the chemical for X-ray film processing, the image can be processed to improve the quality and the image can be saved in digital form. Digital radiography has also been applied in medical research [1–3] and non-destructive testing (NDT) [4–6].

In the medical application, besides for diagnosis of human diseases, X-ray radiography has also been used for diagnosis of animal diseases such as diagnosis of kidney size of rat [7] and diagnosis of skull rabbit with dental disease [8]. However, despite its advantages, digital radiography is expensive which cannot be afforded by some small veterinary clinic in developing countries. The problem can be overcome by modifying conventional radiography using the intensifying screen, light tube and digital camera [9]. In this work, quality of images obtained from modified digital radiography for pet object was analyzed using histogram and contrast to noise ratio (CNR). The images were taken with various exposure factors. Therefore, by analyzing the images, the optimal exposure factors for animal diagnosis using modified digital radiography can be determined.

2. Research Method

Images of the cat with broken bone were taken by exposing the cat to X-ray originated from the modified digital radiograph equipment at Medical Physics Laboratory, Universitas Negeri Semarang.



The digital radiograph consists of conventional radiography Mednif/SF-100BY Mobile X-ray, intensifying screen, Digital Single Lens Reflex (DSLR) camera and a computer. The conventional radiography was modified so that it produces the digital image by replacing the image capturing film using the light tight tube. Then, the image in the intensifying screen is captured and recorded using a DSLR camera which is connected to a computer so that the image can be observed at the computer monitor. The images were taken with various exposure factors which are voltage, current and exposure time. The voltage was varied for 45, 50, 55, 60, 65, and 70 kV.

Meanwhile, the current was varied for 16, 32 and 63 mA. For exposure time, the value was varied for 0.16 s, 0.20 s, and 0.25 s. The image quality was then analyzed regarding CNR and histogram.

CNR analysis was done by implementing MATLAB software. CNR determines the image performance (contrast) and data quality, i.e., noise caused by the radiography system [10]. It is defined as the difference between the mean of the region of interest (ROI) of the object with the mean of the ROI of the background divide by the deviation standard of the background, σ_o as shown in equation (1) below

$$CNR = \frac{S_A - S_B}{\sigma_o} \quad (1)$$

Where S_A is the mean of ROI of the object and S_B is the mean of ROI of the background. The bone of the lower right leg was chosen as the ROI of the object (foreground). Meanwhile, an area near it was chosen as a background as shown in Figure 1.

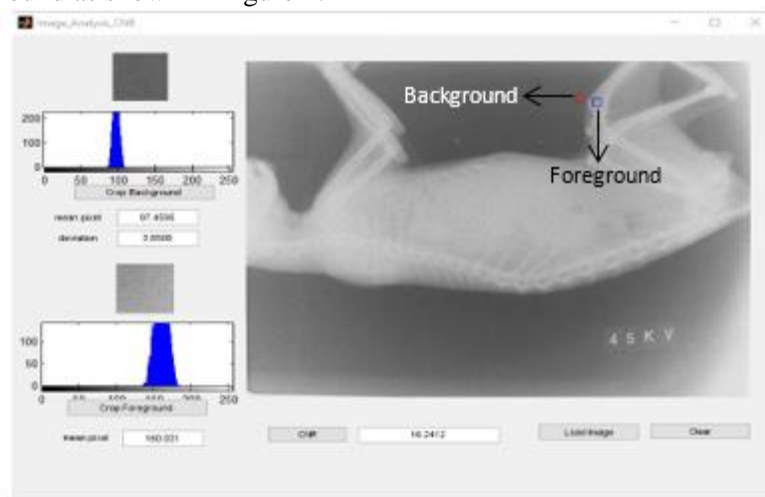


Figure 1. Foreground and background selection for CNR analysis.

3. Results and Discussions

3.1. Variation of voltage

In the variation of voltage, the current and exposure time were maintained at 16mA and 0.20 s, respectively. The histogram analysis of the image with various voltage show that as the voltage increases, the histogram tends to be distributed more at the left side which indicates that the images get darker, as shown in Figure 2. It is shown that for voltage of 50kV and 55kV, the histogram distributed almost uniformly at all grey scale range which means that the images provide good contrast. For the image with the voltage of 60 kV and 65 kV, although the histogram at right side almost vanishes, the grey scale still distributed at half of the grey scale range with almost uniform intensity value. Meanwhile, the histogram for the image taken with the voltage of 70 kV is concentrated at the left side which can be concluded that the image is underexposed.

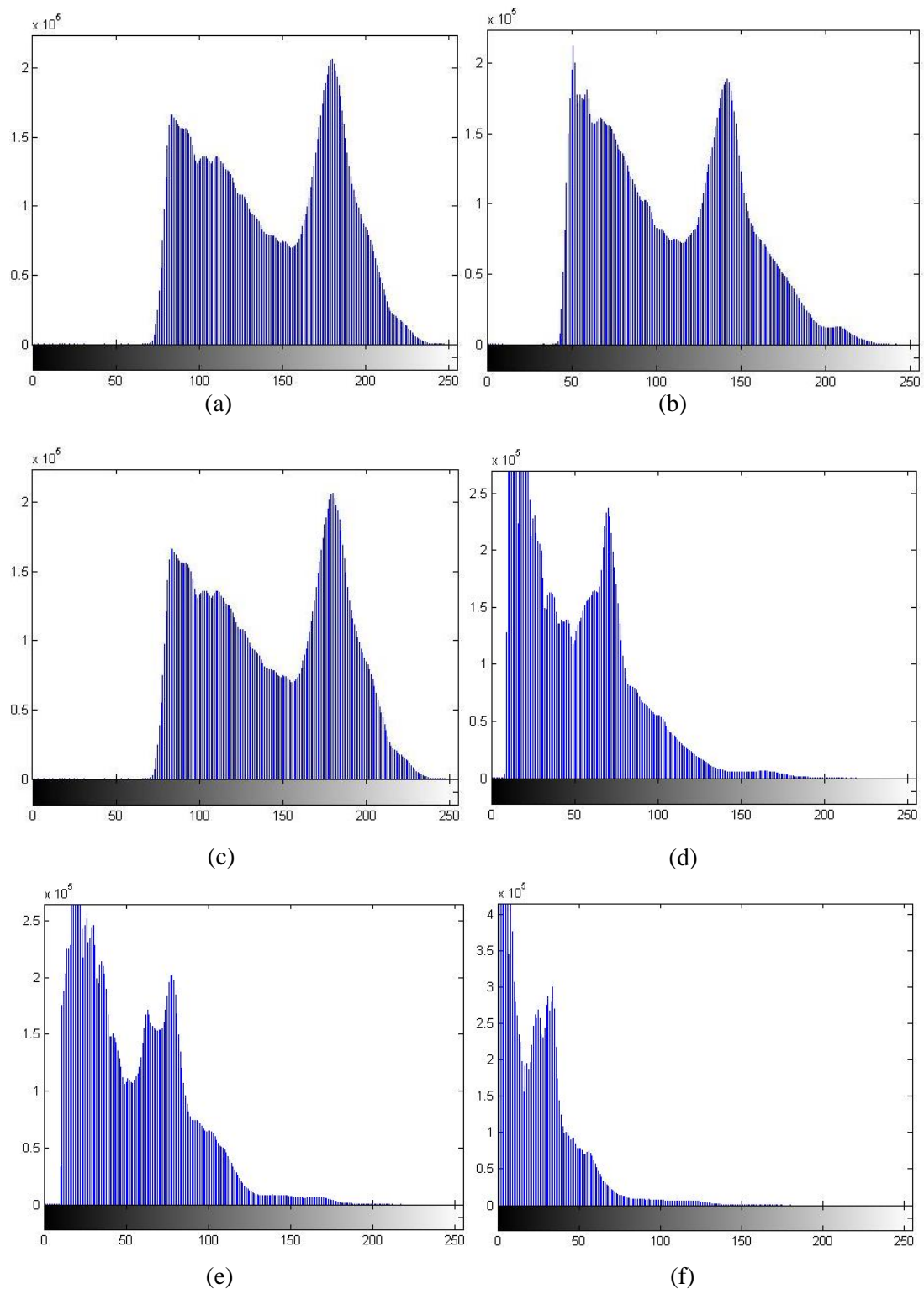


Figure 2. Histogram of image taken with various voltage: 45kV(a), 50kV (b), 55kV (c), 60kV(d), 65kV (e) and 70kV (f).

Regarding CNR, the results show that the CNR increases as the voltage increases until 60 kV as shown in Figure 3. However, CNR decreased when the voltage was further increased. The results agree well with histogram analysis which shows that the higher the voltage, the lower the resulted image contrast. The highest CNR value was obtained at a voltage of 60kV which is 57.249.

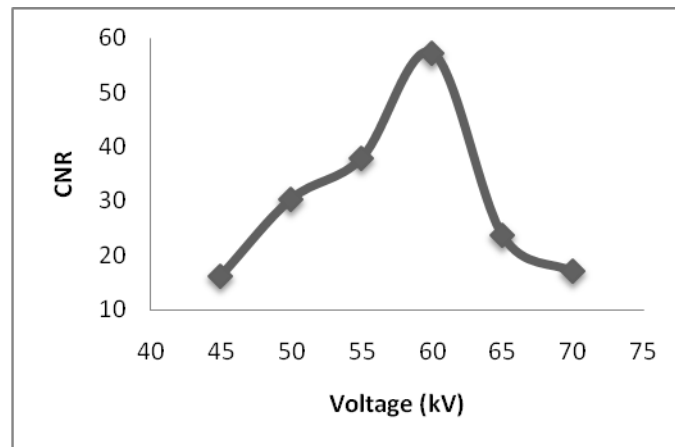


Figure 3. CNR value for images taken with various voltage.

3.2. Variation of Current

Pet images with various current were taken at the voltage of 60kV since the histogram, and CNR analysis showed that image with the voltage of 60kV provides the highest contrast compared to that with other voltage values. Meanwhile, the exposure time was fixed at 0.20s. It is shown that image with the current of 32mA and 63mA are underexposed image since the histogram is concentrated at left side with very narrow grey scale range, as shown in Figure 4. Histogram for the image with the current of 16mA is shown in Figure 2(d), and it is not shown in Figure 4. CNR results show that image with the current of 16mA has the highest CNR which is 57.249 as shown in Table 1. The increase of current resulted in the decrease in CNR. The results agree with the theory of X-ray which states that when high current is applied, the X-ray intensity will be high [9]. Therefore, the image resulted from high-intensity X-ray will has poor image contrast.

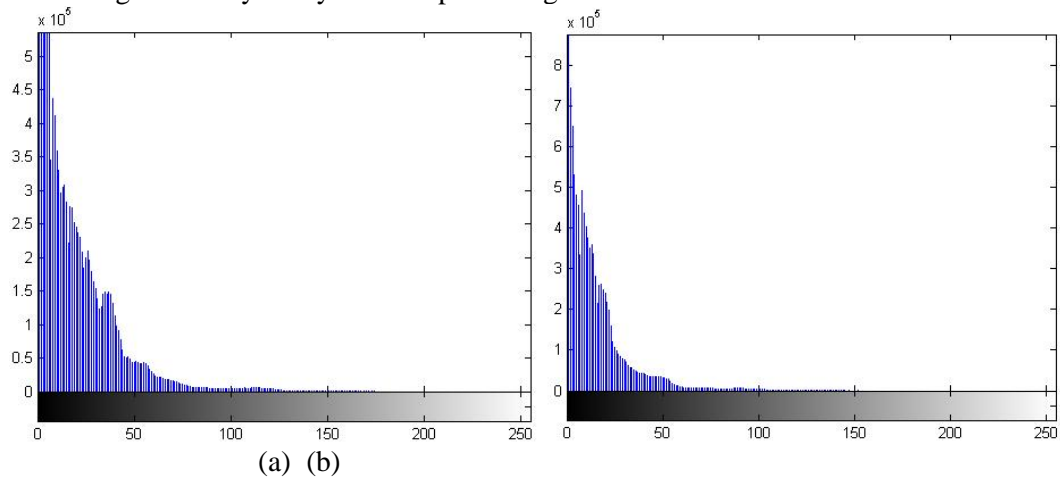


Figure 4. Histogram from the image taken with the current of 32mA (a) and 63mA (b).

Table 1. CNR of the image with various current

Voltage (kV)	Current (mA)	Exposure time(s)	Mean foreground	Mean background	Deviation Standard	CNR
60	16	0,2	63.9977	18.3495	0.79736	57.249
	32		17.7024	0.106073	0.449776	39.1223
	63		16.4626	0.447924	0.761349	21.0346

3.3. Variation of Exposure Time

From the voltage variation and current variation, it was found that the voltage and current which results in high CNR are 60kV and 16mA, respectively. Then, to vary the exposure time, the voltage and current were fixed at those values. Meanwhile, the exposure time was varied for three values which were 0.16s, 0.20s, and 0.25s. Uniform distribution of histogram was found for the image with the exposure time of 0.16s, as shown in Figure 5(a). The histogram is distributed at almost all grey scale values which are from 50 to 250. The opposite was observed at the exposure time of 0.25s which is shown in Figure 5(b). It is shown that the histogram has a high intensity at grey values of 0 to 50 which confirmed that the image has poor quality. Histogram for the image with the exposure time of 0.20s is shown in Figure 2(d) which covers almost all grey values with lower uniform intensity compared to that of the image with the exposure time of 0.16s. It can be explained that the low quality of the image with high exposure time is due to a large amount of radiation that received by the object. A large amount of radiation reduces the sharpness of the image, which is shown by a low uniform histogram. Again, for CNR analysis, the highest CNR value is 57.249 which is CNR for an image with an exposure time of 0.20s. The image with an exposure time of 0.16s and 0.20s are shown in Figure 6.

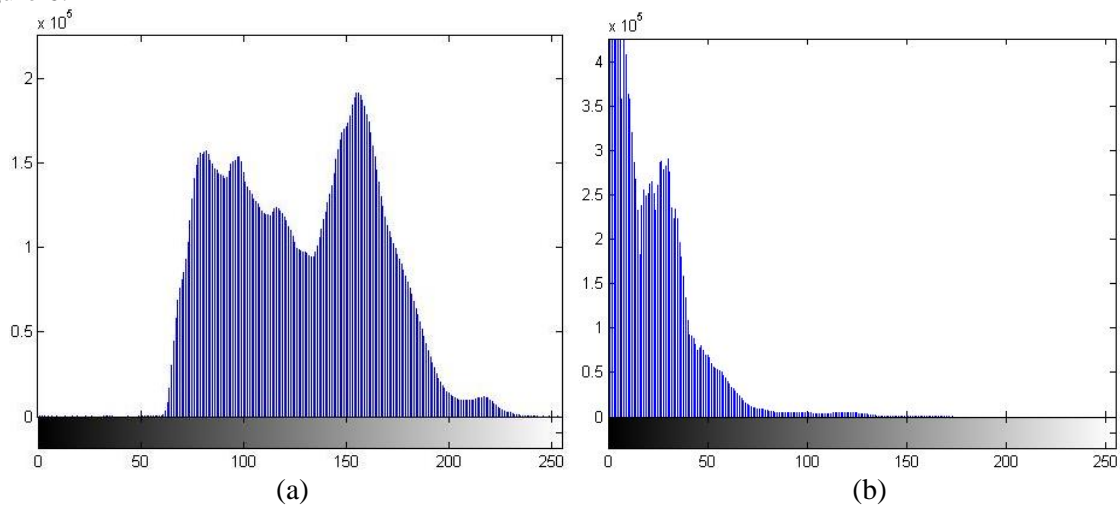


Figure 5. Histogram for image with exposure time of 0.16s (a) and 0.25s (b).

Table 2. CNR of the image with a various exposure time

Voltage (kV)	Current (mA)	Exposure Time (s)	Mean foreground	Mean background	Deviation standard	CNR
60	16	0.16	127.488	75.0243	2.45169	21.3990
		0.20	63.9977	18.3495	0.79736	57.2490
		0.25	22.7190	2.09167	1.23210	16.7410

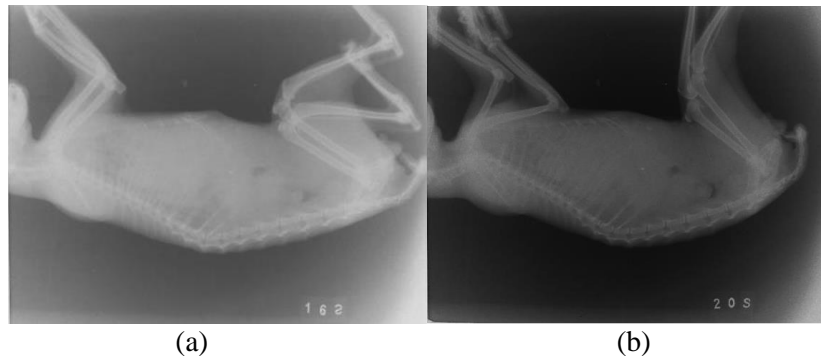


Figure 6. Image with exposure time of 0.16s (a) and 0.20s (b).

4. Conclusions

CNR and histogram analysis of pet images obtained from various exposure factors have been done. The results show that an optimum voltage value is 60kV. It is also shown that a further increase in voltage resulted in low histogram uniformity and low CNR. Regarding current and exposure time, the optimum values are 16 mA and 0.20s, respectively with CNR value of 57.2490 and histogram distribution in grey scale of 0 to 200.

Acknowledgments

We would like to thank Universitas Negeri Semarang for funding the research. Our gratitude also goes to the members of Physics Department, Universitas Negeri Semarang for their helpful discussion throughout the completion of this work.

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