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Study on the Standardization of Signal Intensity Scale of Pixel Value in Digital Radiography

[1]Joon-Koo Choi, [2]Gha-Jung Kim, [3]Dong-Hee Hong, [4]Hyeong-Gyun Kim and [5]Dong-Kyoon Han
[1]Department of Radiological Science, Far East University, 76-32 Daehak-gil, Gamgok-myeon, Eumsung-gun, jk2434/27601 Chungcheongbuk-do, Korea
[2]Department of Radiological Science, Far East University, 76-32 Daehak-gil, Gamgok-myeon, Eumsung-gun, gj4269/27601 Chungcheongbuk-do, Korea
[3]Department of Radiological Science, Far East University, 76-32 Daehak-gil, Gamgok-myeon, Eumsung-gun, dh1602/27601 Chungcheongbuk-do, Korea
[4]Department of Radiological Science, Far East University, 76-32 Daehak-gil, Gamgok-myeon, Eumsung-gun, hg7818 /27601 Chungcheongbuk-do, Korea
[5]Department of Radiological Science, Eul Ji University, 553 Sanseong-dareo, Sujeong-gu, Seongnam-si, dk6298/13135 Gyeonggi-do, Korea

Abstract: The digital radiography image shows contrast by the difference between pixel values created in accordance with absorbance difference of transmitted X-ray to object. The purpose of this study is to propose the need of standardization of pixel value representation in digital radiography image. The unprocessed images and processed images are obtained through various types of X-ray equipment and analyzed pixel values. As the result of pixel value analysis, the unprocessed images represented pixel values in accordance with X-ray signal intensity while processed images represented pixel values in accordance with gray scale. In order to understand the relationship between radiation dose and pixel value in digital radiography image, the pixel value representation which reflects X-ray signal intensity is necessary.

Key words: Digital radiography, pixel value, gray scale, signal intensity, X-ray, radiation

INTRODUCTION

With the introduction of CR (Computed Radiography) that uses IP (Image Plate) in the mid-1980s, the plain radiography system was also digitized (Sonoda *et al*., 1983; Dobbins *et al*., 1995). Since then, digital radiation technology based on CR progressed further with the development of FPD (Flat Panel Detector) that allows for information to be directly converted into digital signals, leading to the emergence of DR (Digital Radiography) (Floyd Jr *et al*., 2001). DR reduces the radiation but provides the same or better image quality as the screen film system. It also has the advantage of communication through digital networking and research flow and ease of storage (Spahn *et al*., 2000). Recently, the DR system is fast replacing the analog radiation system (Korner *et al*., 2007). Digital radiography goes through the process of sampling, quantization, coding and finally the representation of the brightness of the image using pixel values (Williams *et al*., 2007). The pixel value reflect the signal strength of the X-ray that passes through that vary depending on the level of absorption by the object (Samei and Flynn, 2003). In the analog film/screen radiography, the parts where a lot of X-ray passes through is shown as darker while the part that does not pass through much X-ray appears brighter. In thoracic radiography, the lungs have a large amount of X-ray passing through, making a large part of the agent darker. Meanwhile, the bone area passes less X-ray and therefore it appears lighter (Fig. 1).

In general, digital images have pixel values that refer to the minimum unit of the image. Luminance only delivers the information (Prokop *et al*., 2003). Such black and white images consist of a gray scale, showing black which has the lowest luminance to white with the highest luminance (Sternberg, 1986). The standard for the gray scale in digital images is that the closer it is to white, the higher the luminance and therefore the higher the pixel value. Meanwhile, the closer it gets to black, the lower the luminance is and therefore, the pixel value would be close to zero. However, the gray scale in radiography is such that when there is a strong signal for X-ray it appears darker and when there is a weak signal it appears lighter (Fig. 2).

Corresponding Author: Dong-Hee-Hong, Department of Radiological Science, Far East University, 76-32 Daehak-gil, Gamgok-myeon, Eumsung-gun, dh1602/27601 Chungcheongbuk-do, Korea

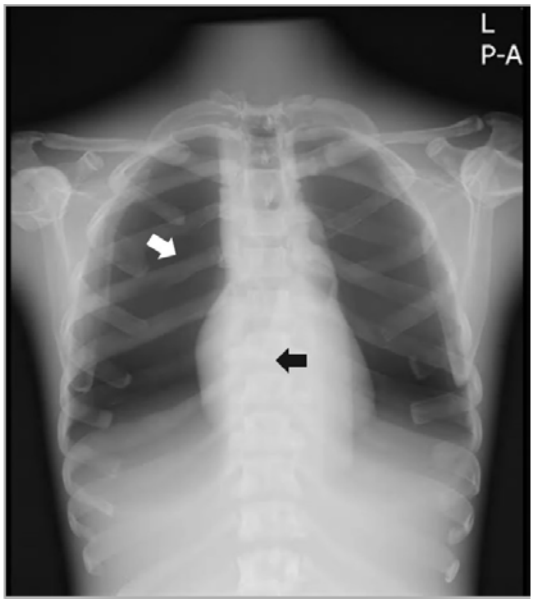

Fig. 1: White arrow is high signal, black arrow is low signal; a) Gray scale and b) Single intensity scale

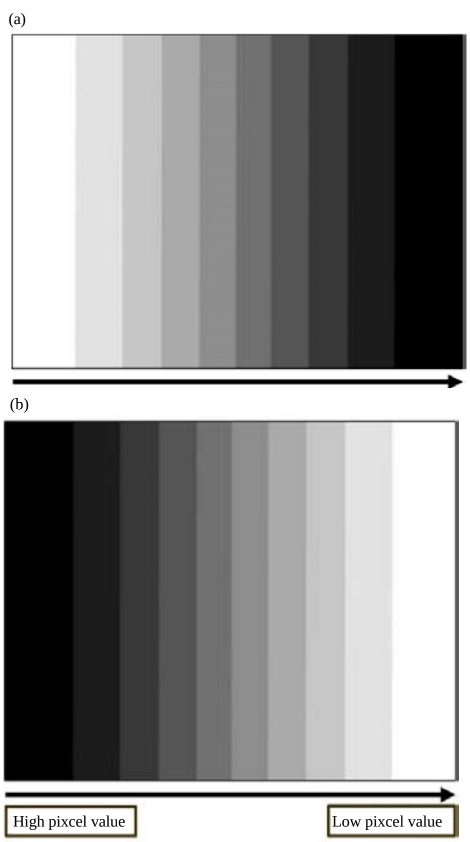

Fig. 2: a) Gray scale and b) Signal intensity scale in plain radiography

Literature review: One of the most important steps in producing and analyzing medical images is the method of enhancing the image which means to enhance the clarity of the image (Janani *et al*., 2015). In the future, quantitative analysis of digital radiography will use CAD (Computer Aided Diagnosis) that automatically detects the abnormal areas through pixel value analysis (Sukassini and Velmurugan, 2015). To understand the characteristics of the image in the spatial and frequency fields it is important to understand the relation between signal intensity and pixel value. Digital radiography matches the digital image value to the luminance in accordance with the GSDF (Grayscale Standard Display Function) defined in the digital image and communication. For the JND index j, the formula to calculate an approximate value of the luminance L (j) is given as follows (Mustra *et al*., 2008).

$$\text{Log } L(j) = \frac{a + c\ln j + e(\ln j)^2 + g(\ln j)^3 + m(\ln j)^4}{1 + b\ln j + d(\text{inj})^2 + f(\text{inj})^3 + h(\text{inj})^4 + k(\text{inj})^5}$$

The pixel value of digital radiography can be expressed in the opposite way of displaying the pixel value in accordance with the signal intensity of the X-ray if, depending on the equipment or the PACS (Picture Archiving and Communication System) viewer, a general grey scale display method is followed. The purpose of this study is to show why the expression of a pixel value that reflects the signal intensity of the X-ray is important in understanding the relation between radiation quantity and pixel value and to suggest the need for standardization of pixel value that reflects the X-ray signal intensity in digital radiography.

MATERIALS AND METHODS

In plain radiography an IDR (Indirect Digital Radiography) was applied for the CR of the IP-type (Konica Redius/Japan) as well as the DR detector (Comed Tatan 2000/Korea) of CCD (Charge Coupled Device)-type and the FPD (Flat Panel Detector) (Canon/Japan, Philips/Netherlands) of a-Si (Amorphous Silicon)-type. For DDR (Direct Digital Radiography), a DR [FPD (Flat Panel Detector)] (Choongwae VIDIX/Korea) of a-Se (Amorphous Selenium)-type was used. For mammography, the (GE/USA) with IDR and (Lorad/USA) of DDR was used. To analyze the pixel value distribution of the acquired images in each equipment, image J 1.46r (National Institutes of Health, USA) was used.

RESULTS AND DISCUSSION

Step 1: Following the image processing, the raw image, unprocessed image and processed image were acquired from respective equipment (Fig. 3 and 4).

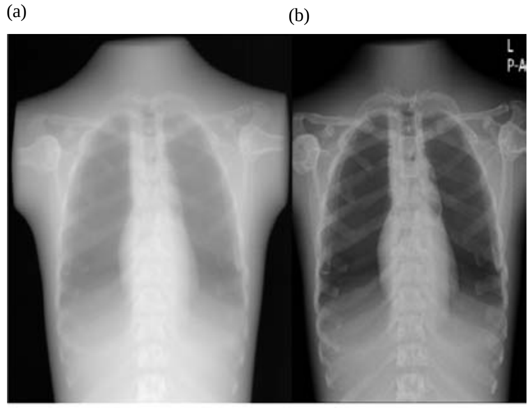

Fig. 3: a) Unprocessed image and b) Processed image in plain radiography

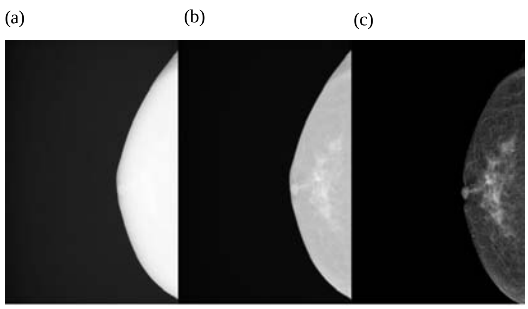

Fig. 4: a) Raw image; b) Unprocessed image and c) Processed image in mammography

Step 2: After differentiating the unprocessed image and processed image, the pixel values are then taken to use the image J analysis program. By applying the mean pixel value, plot profile, surface profile and 3D analysis, the pixel value representation is checked.

After this step in jpeg which is an image it appeared to be all gray scale but for unprocessed images and processed images, the pixel value representation was small or opposite. In the chest image acquired using a chest phantom, the mean pixel value, plot profile and 3D analysis were used. The result was that the pixel values of both unprocessed images and processed images showed a signal intensity scale while the jpeg image showed a gray scale (Fig. 5 and 6).

For the mammography, images were acquired from the third step. By analyzing the mean pixel value and plot, the raw image showed the pixel value to have a signal intensity scale while the unprocessed image and processed image as well as the jpeg were all expressed through a gray scale (Fig. 7).

In the CCD-type DR that used a step wedge, a surface profile analysis was conducted to confirm that the pixel value of the unprocessed image, processed image and jpeg file all were expressed through a gray scale (Fig. 8).

An analysis of the pixel value of the unprocessed images and processed images acquired showed that the pixel value representation was either same or different depending on the image processing procedure (Table 1).

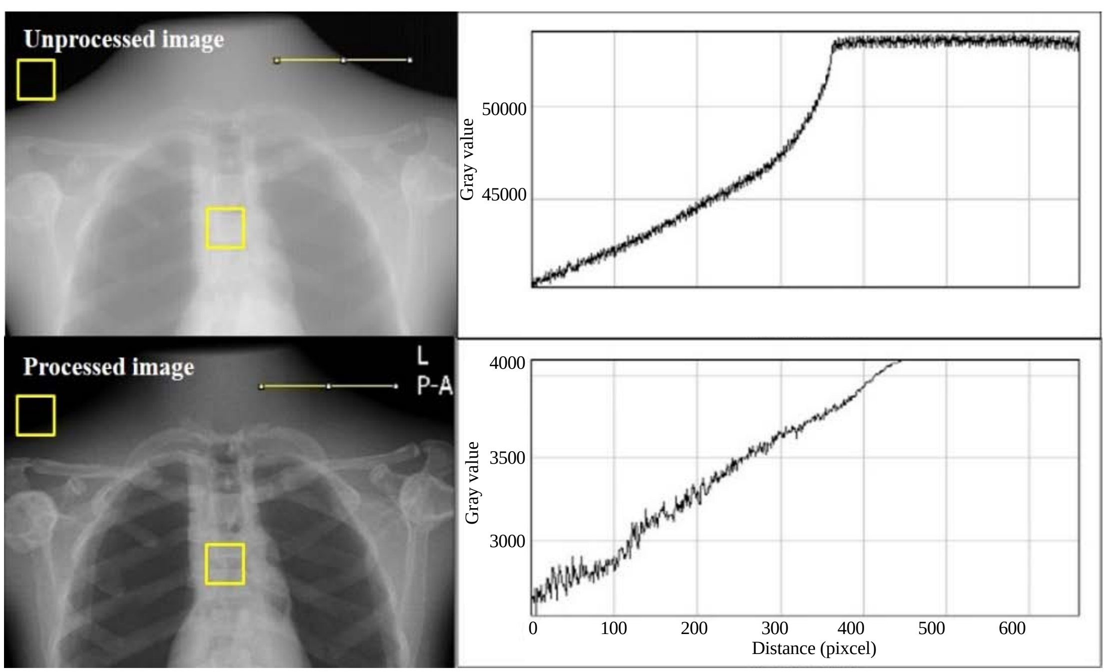

Fig. 5: Mean pixel value and plot profile in plain radiography

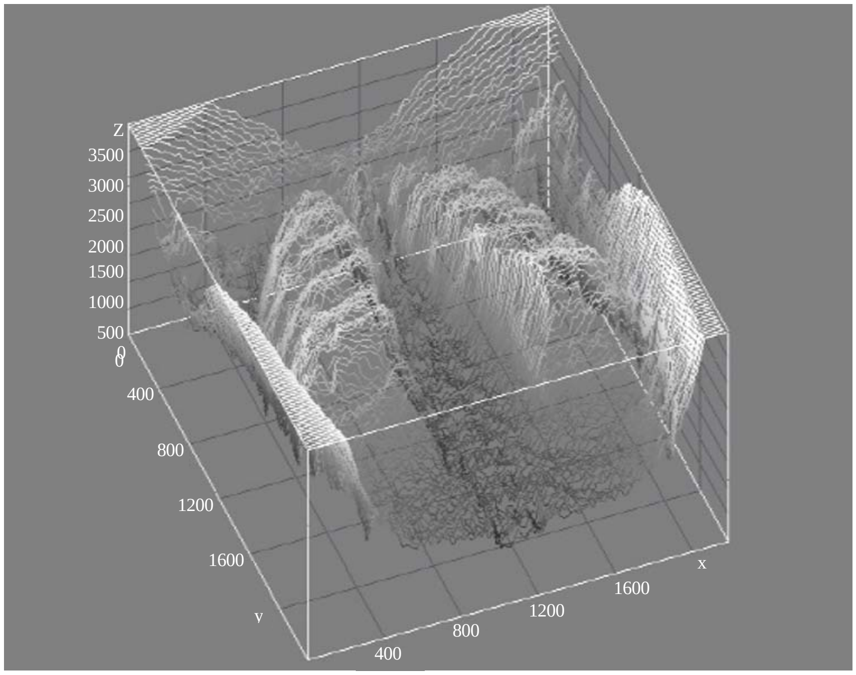

Fig. 6: 3D rendering by pixel value in plain radiography

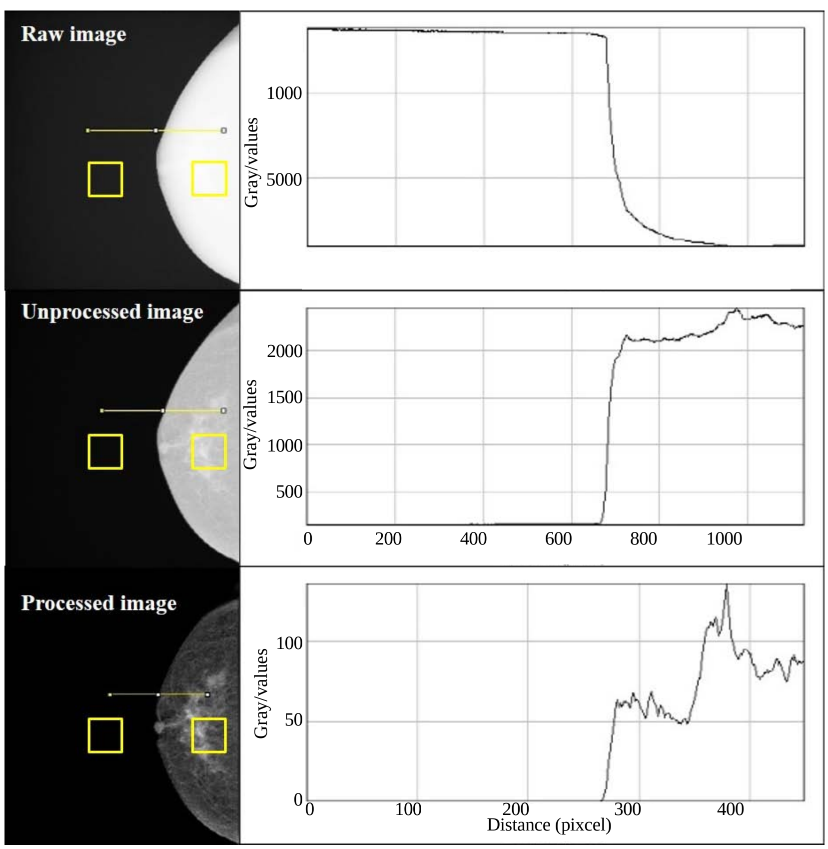

Fig. 7: Mean pixel value and plot profile in mammography

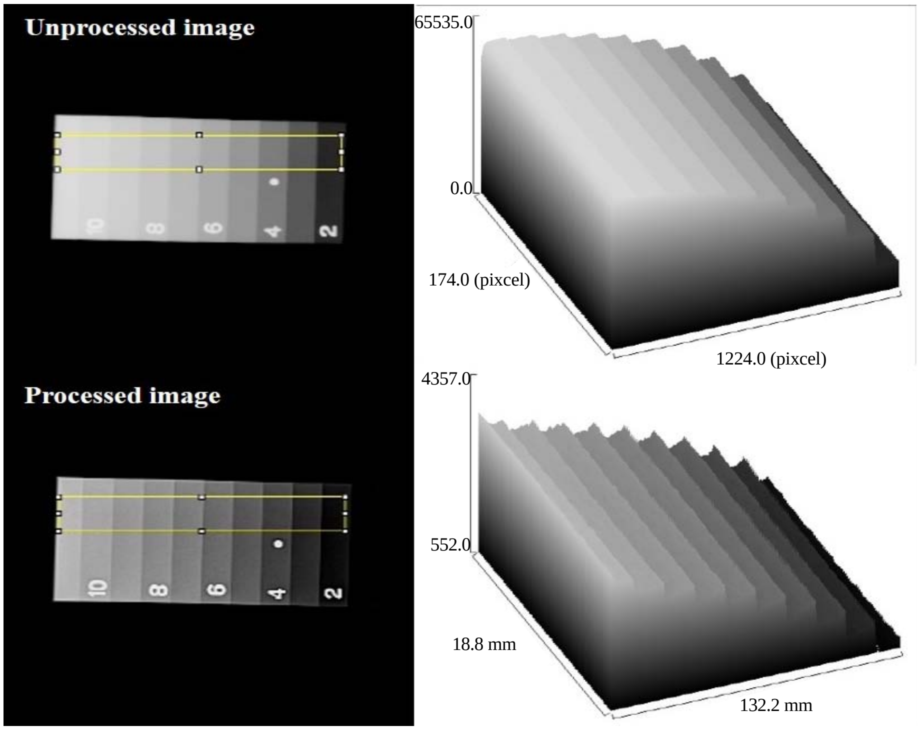

Fig. 8: Surface profile in CCD-type DR

Table 1: Representation of pixel value by manufacture

Class/Species	Type	Manufacture	Unprocessed	Processed	JPEG
Plain radiography					
CR	IP	A	Signal scale	Signal scale	Gray scale
IDR	CCD	B	Gray scale	Gray scale	Gray scale
	a-Si	C	Signal scale	Signal scale	Gray scale
		D	Signal scale	Signal scale	Gray scale
Mammography					
DDR	a-Se	E	Signal scale	Gray scale	Gray scale
IDR	a-Si	F	Signal scale	Gray scale	Gray scale
DDR	a-Se	G	Signal scale	Gray scale	Gray scale

CONCLUSION

Dark parts in digital X-ray images show areas where the signal intensity is high while the lighter parts are areas where the signal intensity is low. Therefore, it is easier to understand digital radiography as having a higher pixel value in dark parts and a lower pixel value in light parts. If the gray scale that is generally applied to digital imaging is used to express radiography where the bright areas represent high pixel value and dark parts represent low pixel value it is difficult to understand the characteristics of the image in accordance with the signal intensity. As seen in the study results, there is no standardization across different equipment, unprocessed images are expressed in pixel value that corresponds to signal intensity while processed images are expressed in the gray scale. Because the pixel value representation of unprocessed images and processed images in X-ray equipment do not match and there is no standardization in the way pixel value that reflects the signal intensity of X-ray across different equipment it is difficult to understand the characteristics of X-ray images. In particular, processed images that are used for diagnosis express the pixel value in the same way it is done in digital photography, making it impossible to reflect the relation between the transmission dose and the characteristics of the radiography. Therefore, in digital radiography, the bright areas must be representative of low pixel value and the dark areas of high pixel value in accordance with the X-ray transmission dose. The expression methods of pixel values for unprocessed and processed images too, need to be standardized way that reflects the signal intensity.

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