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

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Abstract

Objectives: 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. Methods/Statistical Analysis: The unprocessed images and processed images are obtained through various types of X-ray equipment and analyzed pixel values. Findings: 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. Improvements/Applications: 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.

Keywords: Digital Radiography, Gray Scale, Pixel Value, Signal Intensity

1. Introduction

With the introduction of CR (Computed Radiography) that uses IP (Image Plate) in the mid-1980s, the Plain radiography system was also digitized¹². 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)³. 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 workflow, and ease of storage⁴. Recently, the DR system is fast replacing the analog radiation system³. Digital radiography goes through the process of sampling, quantization, coding, and finally the representation of the brightness of the image using pixel values⁵. The pixel value reflects the signal strength of the X-ray that passes through that vary depending on the level of absorption by the object⁷. In the analog Film/Screen radiography, the part 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 as shown in Figure 1.

In general, digital images have pixel values that refer to the minimum unit of the image. Luminance only delivers the information⁶. Such black and white images consist of a gray scale, showing black which has the lowest luminance to white with the highest luminance⁶. 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 as shown in Figure 2.

Figure 1. White arrow is high signal, Black arrow is low signal.

Figure 2. Gray scale and signal intensity scale in plain radiography.

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. In the future, quantitative analysis of digital radiography will use CAD (Computer Aided Diagnosis) that automatically detects the abnormal areas through pixel value analysis. 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, the formula to calculate an approximate value of the luminance $L(j)$ is given as follows.

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.

Figure 3. Unprocessed image and processed image in plain radiography.

Figure 4. Raw image, unprocessed image and processed image in mammography.

2. Proposed Work

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.

**Step 1:** Following the image processing, the raw image, unprocessed image and processed image were acquired from respective equipment as shown in Figures 3 and 4.

**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.

![Figure 5](image1.png)
**Figure 5.** Mean pixel value and plot profile in plain radiography.

![Figure 6](image2.png)
**Figure 6.** 3D rendering by pixel value in plain radiography.

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 as shown in Figures 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 as shown in Figure 7.

![Figure 7](image3.png)
**Figure 7.** Mean pixel value and plot profile in mammography.

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 as shown in Figure 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 as shown in Table 1.

### 3. 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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5. References

1. Sonoda M, Takano M, Miyahara J. Computed radiography utilizing scanning laser stimulated luminescence. Radiology. 1983; 148(3):833–8.
2. Dobbins JT, Ergun DL, Rutz L. DQE(f) of four generations of computed radiography acquisition devices. Medical Physics. 1995; 22(10):1581–93.
3. Floyd CE, Warp RJ, Dobbins JT. Imaging characteristics of an amorphous silicon flat-panel detector for digital chest radiography. Radiology. 2001; 218(3):683–8.
4. Spahn M, Strotzer M, Volk M. Digital radiography with a large-area, amorphous-silicon, flat-panel X-ray detector system. Investigative Radiology. 2000; 35(4):260–6.
5. Korner M, Weber CH, Wirth S. Advances in digital radiography: physical principles and system overview. RadioGraphics. 2007; 27(3):675–86.

6. Williams MB, Krupinski EA, Strauss KJ. Digital radiography image quality: Image acquisition. Journal of American College of Radiology. 2007; 4(6):371–88.

7. Samei E, Flynn MJ. An experimental comparison of detector performance for direct and indirect digital radiography systems. Medical Physics. 2003; 30(4):608–22.

8. Prokop M, Neitzel U, Schaefer-Prokop C. Principles of image processing in digital chest radiography. Journal of Thoracic Imaging. 2003; 18(3):148–64.

9. Sternberg SR. Grayscale morphology. Computer Vision, Graphics, and Image Processing. 1986; 35(3):333–55.

10. Janani P, Premaladha J, Ravichandran KS. Image enhancement techniques: A study. Indian Journal of Science and Technology. 2015; 8(22):1–12.

11. Sukassini MP, Velmurugan T. A survey on the analysis of segmentation techniques in mammogram images. Indian Journal of Science and Technology. 2015; 8(22):1–8.

12. Mustra M, Delac K, Grgic M. Overview of the DICOM standard. 50th International Symposium ELMAR; 2008. p. 39–44.