Performance Evaluation of Digital Radiography Antiscatter Grids using Film Digitizers

Hyoung-Koo Lee[a], Jung-Ae Lee[a], Sung-Hyun Kim[a], Dong-Su Ho[a], Do-Il Kim[a], Tae-Suk Suh[a], Bo-Young Choe[a], Jin-Soo Kim[b] and Jin-Won Kim[b]

[a]*Dept. of Biomedical Engineering, College of Medicine, The Catholic University of Korea, 505 Banpo-Dong, Seocho-Gu, Seoul 137-701 Korea*
[b]*Jungwon Precision Ind. Co., 794-19, Bangbae-Dong, Seocho-Gu, Seoul 137-060 Korea*
e-mail: hklee@catholic.ac.kr

ABSTRACT

We propose a method which can replace the DR when measuring performance evaluation parameters of antiscatter grids for DR. We used conventional x-ray films to produce grid images, which were scanned by a film digitizer. The digitizer could provide sampling interval of 87 micrometers and pixel depth of 12 bits. Grid line frequencies were measured using aliasing effect and non-uniformities of grids were measured by transforming scanned pixel values of film images into optical densities.

Keywords: antiscatter grid, digital radiography, film digitizer.

1. INTRODUCTION

Antiscatter grids have been the best choice for removal of scattered photons during x-ray examinations and have showed good contrast improvement. As the history of antiscatter grids is long, many theoretical and experimental studies of the performance and characteristics of them have been performed. As a result, requirements of grids are well defined and standard methods of measuring grid characteristics and performance are well set, being widely used in x-ray imaging industries. All of these requirements and performance evaluations were, however, focused on improving contrast of x-ray film images. As the digital radiography (DR) is introduced into x-ray imaging technology, contrast of x-ray images is manipulated by not only grids but also digital image processing. During the image processing, shadow of grid lines can be amplified and non-uniformities of grid materials can produce artifacts in the final processed images. Hence, new parameters of performance evaluation of antiscatter grids for DR system should be introduced. Non-uniformity of grids is one of the major evaluation parameter and is measured using DR systems. The method of using DR systems is, however, expensive and influenced by the performance of the DR being used. We propose a method which can replace the DR when measuring performance evaluation parameters of antiscatter grids for DR. We used conventional x-ray films to produce grid images, which were scanned by a film digitizer. The digitizer could provide sampling interval of 87 micrometers and pixel depth of 12 bits. Grid line frequencies were measured using aliasing effect and non-uniformities of grids were measured by transforming scanned pixel values of film images into optical densities.

2. MATERIALS AND METHODS

2.1. X-Ray Exposure

Grids under test were positioned at the locations of grid focal distance from the source position of x-ray tube and x-ray films were positioned in contact with grids. 120 kVp, 200 mA and 0.6 mm focal spot of x-ray beam was exposed to acquire grid images. In order to maintain same position for each exposure, we made a positioning fixture in which grids and film cassette are snapped. This positioning fixture has radio-opaque markers on corners, and by aligning the shadow of these markers on the processed films we could align film images during image processing.

2.2. Film Digitizing

We evaluated two film digitizers from two different companies and chose one by comparing stability and response to optical density. Pixel values of scanned film images shoed a linear relationship with optical densities. Scanned images were saved in 12bit DICOM format.

2.3. X-Ray beam and Digitizer Non-uniformity Correction

Due to heel effect and other properties of x-ray tube, the image of x-ray beam without any object is not uniform. And due to different light output of LEDs and different sensitivity of photosensors in the film digitizer, scanned image of blank film showed strips.

Digitizer non-uniformity was corrected by following equation.

$$S(i,j) = a_1 O_o + a_2 + s(i,j) - s_o(i,j)$$

where, i and j indicate pixel coordinate of scanned image, S is the corrected scanned image, s_o is a scanned image of a blank film, O_o is the optical density of a blank film, s is a scanned image of a film under test, and a_1 and a_2 are coefficients of linear equation between pixel values and optical densities. Non-uniformity in the to x-ray beam was corrected by following equation.

$$S_G(i,j) = b_1\left[\frac{X(i,j)}{X_s(i,j)}\cdot\overline{X}_s\right]^2 + b_2\left[\frac{X(i,j)}{X_s(i,j)}\cdot\overline{X}_s\right] + b_3$$

where, S_G is the corrected image, $X_s(i,j)$ is the exposure of a film without grid at position (i,j), $\overline{X}_s$ is the mean value of X_s, $X(i,j)$is the exposure of a film under test grid at position (i,j), and b_1, b_2 and b_3 are coefficients of quadratic equation between optical densities and exposure.

2.4. Grid Line Frequency

After correction of x-ray beam and scanner non-uniformity, 4096 x 4096 size of ROI was selected from the center of a grid image. Mean gray level of the ROI was calculated and this value was subtracted from the ROI image. Hanning window was applied on the ROI image follwed by 2D FFT. The grid line frequency was calculated using aliasing effect.

$$line\,frequency = 2 \times f_{Nyquist} - f_{measurement}$$

where, $f_{Nyquist}$ indicates the Nyquist frequency of film digitizer.

2.5. Grid Line Visibility

Shadow of grid lines can obscure subtle gray level changes in DR images. In order to analyze the visibility of grid lines, we calculated a ratio of grid line peak and mean background gray levels. Grid line peak value was obtained from the FFT analysis.

2.6. Non-Uniformity of Grid

Non-uniformity of grids was analyzed in two scales: local and overall area. Local non-uniformity was defined as maximum relative difference between mean values of one ROI and its 8 neighbor ROIs. Overall non-uniformity was defined as maximum relative dirrenence of means between one ROI and other ROIs on the whole image. The size of ROI was 1 cm x 1 cm and ROI was selected across whole image except border area.

3. RESULTS

3.1. Grid Line Frequency

Results of grid line frequency measurements are shown in Fig. 1. We applied our method to 12 grids which are supposed to have grid line frequency of 78 lines/cm. Measured line frequencies were in the range of 76.8 ~ 78.6, showing good agreement between measurements and specification. Measurements were repeated using three films and compared in Fig. 1.

3.2. Grid Line Visibility

Results of grid line peak/mean values are shown in Fig. 2. According to results, shadow of grid lines are only about 0.1 ~ 0.2 % of background gray levels. Again measurements over 3 films shows good repeatability.

3.3. Non-Uniformity of Grid

In order to correct non-uniformities due to digitizer and x-ray beam it is important to align films correctly. We used markers during x-ray exposure and by aligning these markers we could align film images correctly. Non-uniformities of x-ray image without any object after x-ray beam and digitizer non-uniformity correction are shown in Table 1. 200 mAs of exposure was used. By applying scanner and x-ray beam non-uniformity correction method, the non-uniformity of x-ray film witout any object is greatly improved, which means by applying this method we could isolate grid images from the x-ray films which were taken with grids.

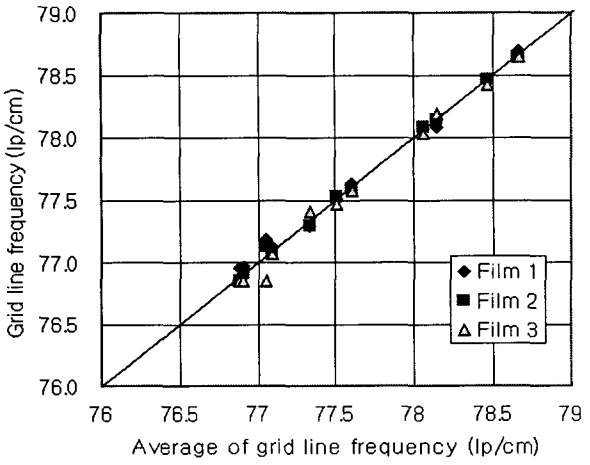

Fig. 1 Grid line frequency measurement

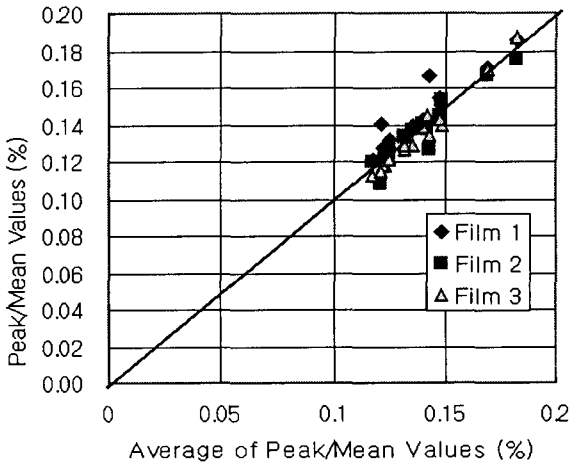

Fig. 2 Grid line Peak/Mean Values

Table 1. Results of x-ray beam and scanner non-uniformity correction.

Focal distance (cm)	Before correction		After scanner non-uniformity correction		After x-ray beam non-uniformity correction	
	Local	Overall	Local	Overall	Local	Overall
100	2.50	18.81	2.13	19.03	0.47	1.51
180	2.10	12.00	1.45	9.73	1.38	7.62

Results of local and overall non-uniformity of grids are shown in Fig. 3 and 4, respectively.

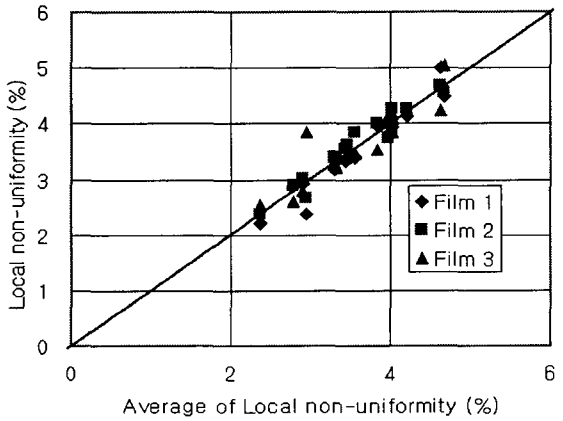

Fig.3 Grid line frequency measurement

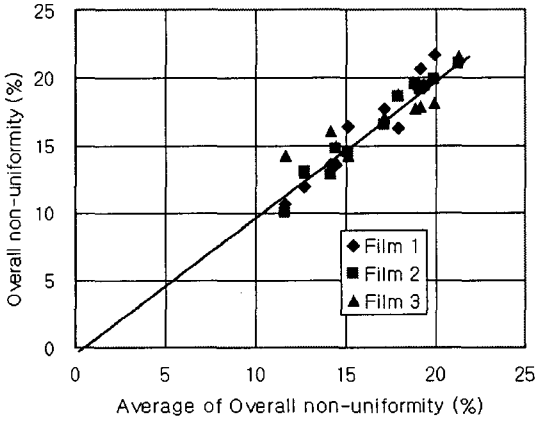

Fig. 4 Grid line Peak/Mean Values

ACKNOWLEDGEMENTS

This work was supported by Ministry of Science and Technology through its National Research Laboratory (NRL) program