Homework #09

1. An exercise in Contrast-Detail Analysis

A Contrast-detail phantom was used to acquire images to be evaluated in this project. This phantom consists of two Lucite slabs with holes of different depths and diameters. There are seven hole-depths for each of the seven hole-diameters. The holes range in diameter from 0.18 to 4.82 mm and in depth from 0.06 to 0.73 mm (Fig 1). The total thickness of the phantom is 23mm. Under standard diagnostic x-ray exposure, the different hole-depth produces different subject contrasts (Table).

Digital images were acquired under 28KVp-0.3mA-3seconds (Fig.2), and 28KVp-0.3mA-9seconds (Fig.3), respectively. The subject contrasts produced by each of the hole-depth under the given x-ray beam quality are listed in the following table.

Please determine the impact of these two x-ray techniques to human observer's detectability (hint: You may want to review the images, derive a contrast detail curve from each image, and compare these two curves). The Table and Figures are given in the following slides.

Hole depth (mm)	Subject Contrast (under the given condition)
0.06	0.4%
0.11	0.73%
0.16	1.1%
0.24	1.6%
0.36	2.4%
0.51	3.5%
0.73	5.0%

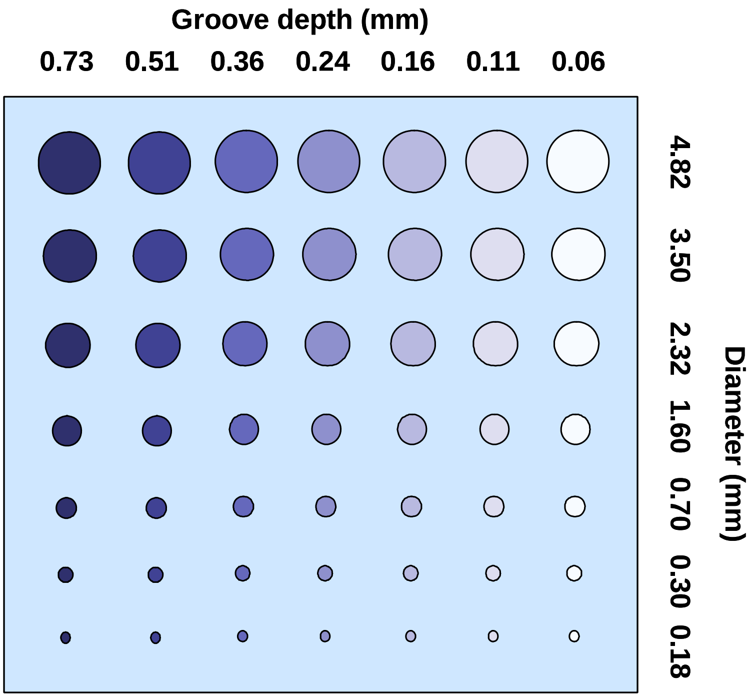


Figure 1. A contrast-detail phantom.

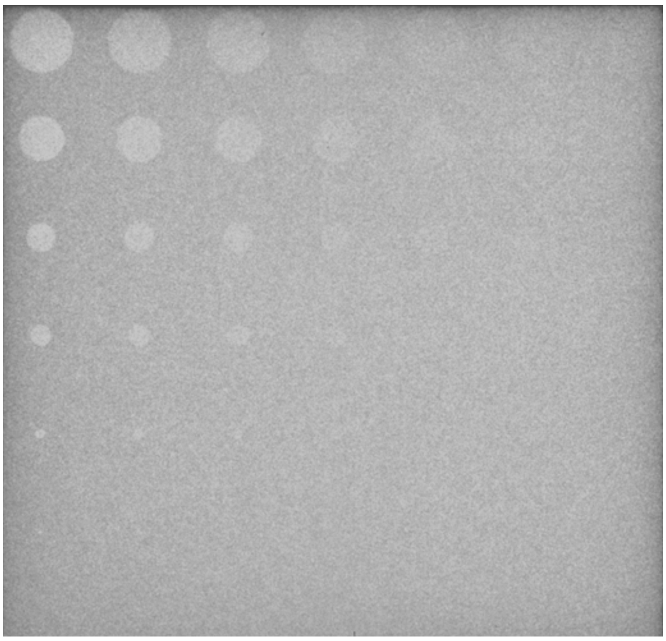


Fig.2: This image was acquired under 28 kVp, 0.3 mA and exposure time of 3 seconds.

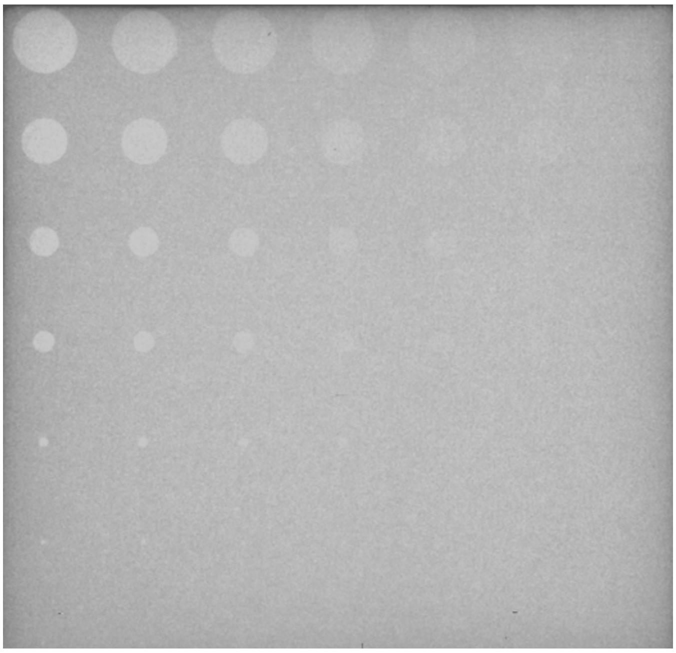
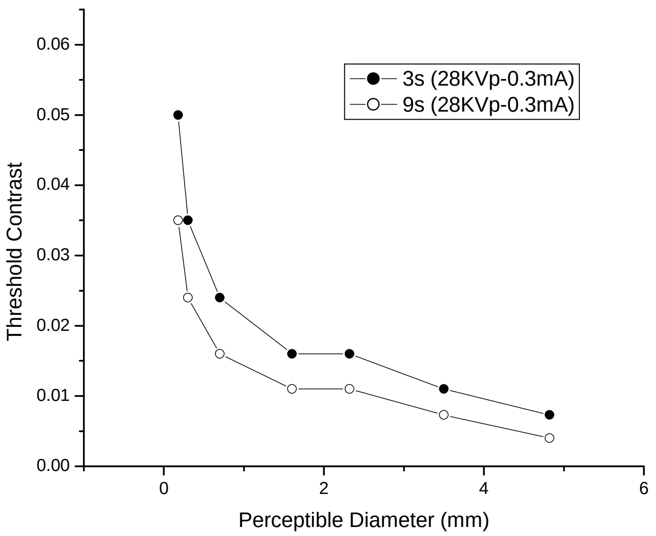


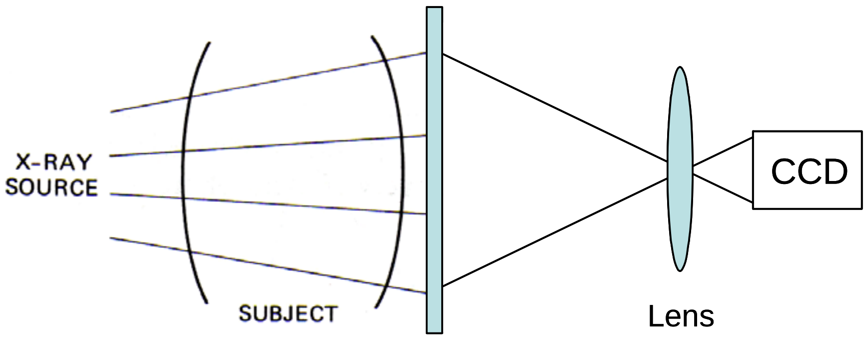
Fig. 3: This image was acquired under 28 kVp, 0.3 mA and exposure time of 9 seconds

Solution:



Contrast-detail curves are shown in the figure, it shows that digital image is acquired under 28KVp-0.3mA-9seconds is better than it is acquired under 28KVp-0.3mA-3seconds conditions.

2. A lens coupled CCD digital radiography is schematically shown, and its technical parameters are given as follows.



scintillating screen

η **:** Absorption efficiency (quantum efficiency) of the scintillating screen, (assume 65%).

g_1 **:** is the gain of the scintillating screen (light photons per absorbed x-ray photon), (assume: 500 light photons / X-ray photon);

g_2 **:** the efficiency of the optical lens system, (assume 1%);

g_3 **:** the quantum efficiency of the CCD camera in electrons per light photon; (assume: 35%).

N_i **:** the average number of x-ray photons falling onto the input phosphor screen (assume: 5,000 x-ray photons)

N_a : total additive noise (a readout noise of 200 electrons for CCD detector)

Is this system an x-ray quantum noise limited system? If yes, why? if no, how much more radiation the patients will have to be exposed in order to achieve an image quality of a x-ray quantum noise limited system.

Solution:

A total quantum gain

$$g_1 = 500$$

$$g_2 = 0.01 \qquad g_1 g_2 = 500 \times 0.01 = 5$$

$$g_3 = 0.35$$

$$g = g_1 g_2 g_3 = 500 \times 0.01 \times 0.35 = 1.75$$

$$N_i = 5000$$

$$N_a = 200$$

Recall eq. 11.20

$$SNR = \frac{C\sqrt{\eta N_i}}{\sqrt{\left(1 + \frac{1}{g_1} + \frac{1}{g_1 g_2} + \frac{1}{g_1 g_2 g_3}\right) + \frac{N_a^2}{\eta N_i \left(g_1 g_2 g_3\right)^2}}}$$

$$= \frac{C\sqrt{\eta N_i}}{\sqrt{\left(1 + \frac{1}{500} + \frac{1}{5} + \frac{1}{1.75}\right) + \frac{200^2}{0.65 \times 5000 \times \left(1.75\right)^2}}}$$

$$\approx \frac{C\sqrt{\eta N_i}}{2.4}$$

This system is not an x-ray quantum noise limited system.

In order to achieve the same image quality (SNR) as if an x-ray quantum noise limited system is used, we assume new radiation the patient will have to be exposed is:

$$N_i' = K \times N_i$$

$$SNR' = \frac{C\sqrt{\eta N'_i}}{\sqrt{\left(1+\frac{1}{g_1}+\frac{1}{g_1 g_2}+\frac{1}{g_1 g_2 g_3}\right)+\frac{N_a^2}{\eta N'_i\left(g_1 g_2 g_3\right)^2}}} \approx C\sqrt{\eta N_i}$$

$\Rightarrow$

$$\frac{C\sqrt{\eta K N_i}}{\sqrt{\left(1+\frac{1}{g_1}+\frac{1}{g_1 g_2}+\frac{1}{g_1 g_2 g_3}\right)+\frac{N_a^2}{\eta K N_i\left(g_1 g_2 g_3\right)^2}}} \approx C\sqrt{\eta N_i}$$

$\Rightarrow$

$$\frac{\sqrt{K}}{\sqrt{\left(1+\frac{1}{500}+\frac{1}{5}+\frac{1}{1.75}\right)+\frac{200^2}{0.65\times K\times 5000\times(1.75)^2}}} \approx 1$$

$\Rightarrow$

$$K = \left(1+\frac{1}{500}+\frac{1}{5}+\frac{1}{1.75}\right)+\frac{200^2}{0.65\times K\times 5000\times(1.75)^2}$$

$$K \approx 3 \Rightarrow N'_i \approx 3N_i$$

The radiation exposure to the patient will have to be increased 2 times.