OBJECTIVE AND SUBJECTIVE IMAGE QUALITY MEASURES OF MEDICAL SCREEN-FILM SYSTEMS

Wan Muhamad Saridan Wan Hassan[1], Yusof Munajat[1] & Shamsul Sahibuddin[2],

[1]Jabatan Fizik, Fakulti Sains, Universiti Teknologi Malaysia,
81310 Skudai, Johor Darul Ta'zim. Tel: 07-5534191, Fax: 07-5566162, Email: saridan@dfiz2.fs.utm.my

[2]Jabatan Sistem dan Kejuruteraan Komputer, Fakulti Sains Komputer dan Sistem Maklumat, Universiti Teknologi Malaysia,
81310 Skudai, Johor Darul Ta'zim.

ABSTRACT

Image quality of Lanex Regular/T Mat G and Lanex Regular/T Mat L screen-film systems was measured objectively by means of noise equivalent quanta (NEQ) and subjectively by means of receiver operating characteristic (ROC) curve analysis to study the link between the two measures. For the objective measure, uniformly exposed radiographs and radiographs of bar pattern test object were used to determine the NEQ. For the subjective measure, detection of simulated lesions in posteroanterior anthropomorphic chest radiographs by an observer was analysed by the ROC methodology. Both measures show that a low frequency signal shows better on Lanex Regular/T Mat L, whilst a high frequency signal shows better on Lanex Regular/T Mat G.

I.   INTRODUCTION

The International Commission on Radiation Units and Measurements (ICRU) has recommended that the assessment of medical imaging technology be based on a joint approach that involves physical measurements, statistical decision theory, and receiver operating characteristic (ROC) analysis [1], which implies both objective and subjective measures are required to evaluate medical imaging systems. The term 'objective measure' refers to physical parameters such as large scale system transfer characteristic, spatial resolution properties, and noise properties which are measured physically. The term 'subjective measure' refers to individual human judgement involvement in quantifying quality, in which ROC analysis is an example. Very often studies in quality of medical images use either objective measure [2, 3, 4] or subjective measure [5, 6] as the measure of quality, and only seldomly one find studies that offer both measures in the treatment of research. This is understandable since a study that involves both measures is expensive and time consuming.

To conform with the recommendation it would thus be of interest to evaluate medical imaging systems in terms of both measures and learn how both are related. In this work, image quality of Lanex Regular/T Mat G (LR/TMG) and Lanex Regular/T Mat L (LR/TML) screen-film systems was measured objectively by means of noise equivalent quanta (NEQ) and subjectively by means of ROC analysis to study the link between the two measures.

II. METHOD AND MATERIALS

II.A. Physical measure

The physical measure of image quality of LR/TMG and LR/TML was quantified by the NEQ. To accomplish this, the average gamma of each radiograph was computed, both the MTF and the NPS data of each screen-film system were interpolated and these values were used to compute the NEQ [7]. Link of this physical measure of image quality are sought with the following subjective measure (section II.B).

II.B. Subjective measure

For the subjective measure, the detection of simulated lesions in posteroanterior (PA) anthropomorphic chest phantom radiographs of LR/TMG and LR/TML by an observer was analysed by the ROC methodology [6]. Data from a previous study was reanalysed for this work [8].

Ten templates were created using paper sheets. The template was subdivided into 15 fields of approximately equal size. When the template was superimposed onto the chest phantom, it divided the lungs and mediastinum regions into 15 fields of approximately equal size. Three types of lesions namely pulmonary nodules, lines, and micronodular opacities were chosen to represent different requirements in terms of the spatial and contrast resolution of an imaging system. The lesions were simulated with candle wax, folded aluminium foil, and green beans, respectively.

Each of the three types of lesions was taped into 75 of the 150 fields, according to an independent random number sequence. Each field could be totally empty or contain one or more of the three lesions. Each lesion type, however, was positioned only one time per field. Different random number sequences were chosen for each lesion type.

The candle wax nodules were of the shape of rounded disks, made by cutting candle sticks, and trimming sharp edges so that they become rounded. The diameters were 1 cm, and the thickness were 5 mm. The disks were taped on the field with flat side to the paper. The aluminium lines were made by folding 6 folds of aluminium foil into strips. The height of the strips was 1 cm. The strips were taped perpendicularly on the paper. The micronodular green beans were oval in shape of 3–4 mm in diameter. A cluster of 10 grains of them were tape on the paper in the field that are supposed to contain them.

The template was taped to the anthropomorphic chest phantom, and the experimental set-up as shown in Figure 1 was used to produce the PA chest X-ray images.

Twenty images from the two screen-film systems were obtained, 10 for LR/TMG and 10 for LR/TML. Following the exposure factor used for the PA chest X-ray examination in the installation, the tube potential was 67 kVp, and the focus-to-film distance was 180 cm.

The images were read by an observer. For each test field, the reader was asked to separately state his confidence of the presence of a nodule, a line, or micronodular opacities. The reader was to use a five-level scale to rank his confidence for each observation: 1. definitely negative, 2. probably negative, 3. indeterminate, 4. probably positive, 5. definitely positive.

Data were analysed by the ROC curve method [9], and an observer performance was based on the area under the ROC curve [10]. Observer's detection performance was analysed according to the type of lesion (nodule, line, or micronodule) in the field in which the lesion is located.

III.   RESULTS AND DISCUSSION

Figure 2 shows the NEQ of LR/TMG and LR/TML screen-film combinations. The NEQ of LR/TMG is lower than that of LR/TML for spatial frequency 0-0.7 cycles/mm, but the NEQ of the former is higher than that of the latter for spatial frequency greater than 0.7 cycles/mm. Relatively this means, in terms of device performance, a low frequency signal shows better on LR/TML, but a high frequency signal shows better on LR/TMG [1].

Figure 3 shows the ROC curves for detecting nodules, micronodules, and lines employing LR/TMG and LR/TML, whilst Table 1 gives the areas under the respective ROC curves. Using area as a measure of detection, i.e. the area under the ROC curve corresponds to the probability of correctly identifying which of the two stimuli is 'noise' and which is 'signal plus noise' [10], the curves show that modules and micronodules show better on LR/TML whilst lines show better on LR/TMG.

The spatial frequency content of the lesion signals are: 0.1 cycle/mm for nodules, 0.3 cycles/mm for micronodules, and 1.0 cycle/mm for lines. For nodules and micronodules the objective measure indicates that the NEQ of LR/TML is higher than that of LR/TMG (Figure 2). This agrees with the subjective measure which says that better detection of the lesions using LR/TML than LR/TMG (Figure 3). For lines, the NEQ of LR/TMG is higher than that of LR/TML (Figure 2) and this agrees with the observer performance exhibiting better detection of the lesions using LR/TMG than LR/TML (Figure 3). Thus we find that our objective and subjective measures correlate well. Leppert *et. al.* [6] used the ROC analysis to compare detection of simulated chest lesions between a conventional screen-film combination (Kodak's Lanex Medium/T Mat L), an asymmetric screen-film system (Kodak's InSight VHC system), and storage phosphor radiography (Fuji AC-1 storage phosphor radiography unit), but did not include the NEQ of the systems compared. A study by Buhr *et. al.* [11] attempted to correlate a physical image quality measure (i.e. the noise of the screen-film radiographs) with a subjective measure (i.e. the visual detectability of simulated lung nodules in chest images by the ROC analysis). In the present study the NEQ (a more comprehensive objective measure) was used instead of just the noise properties as in Buhr *et. al.* work.

IV.   CONCLUSION

Image quality of Lanex Regular/T Mat G and Lanex Regular/T Mat L screen-film systems was evaluated objectively by the NEQ and subjectively by the ROC methodology. Both measures indicate that a low frequency signal shows better on Lanex Regular/T Mat L whilst a high frequency signal shows better on Lanex Regular/T Mat G, showing the objective and subjective measures correlate well.

ACKNOWLEDGEMENT

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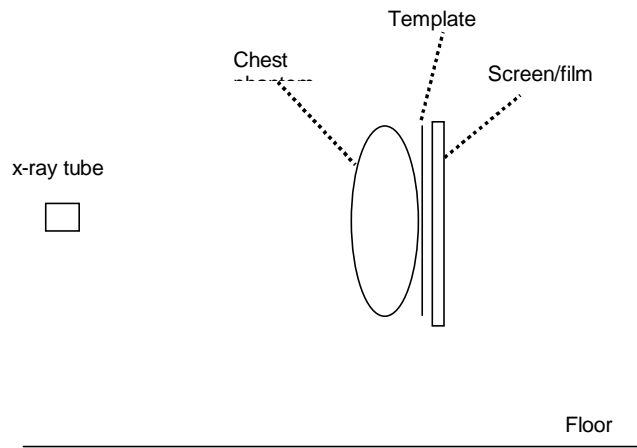
FIGURE 1. Experimental set-up for acquiring chest phantom images.
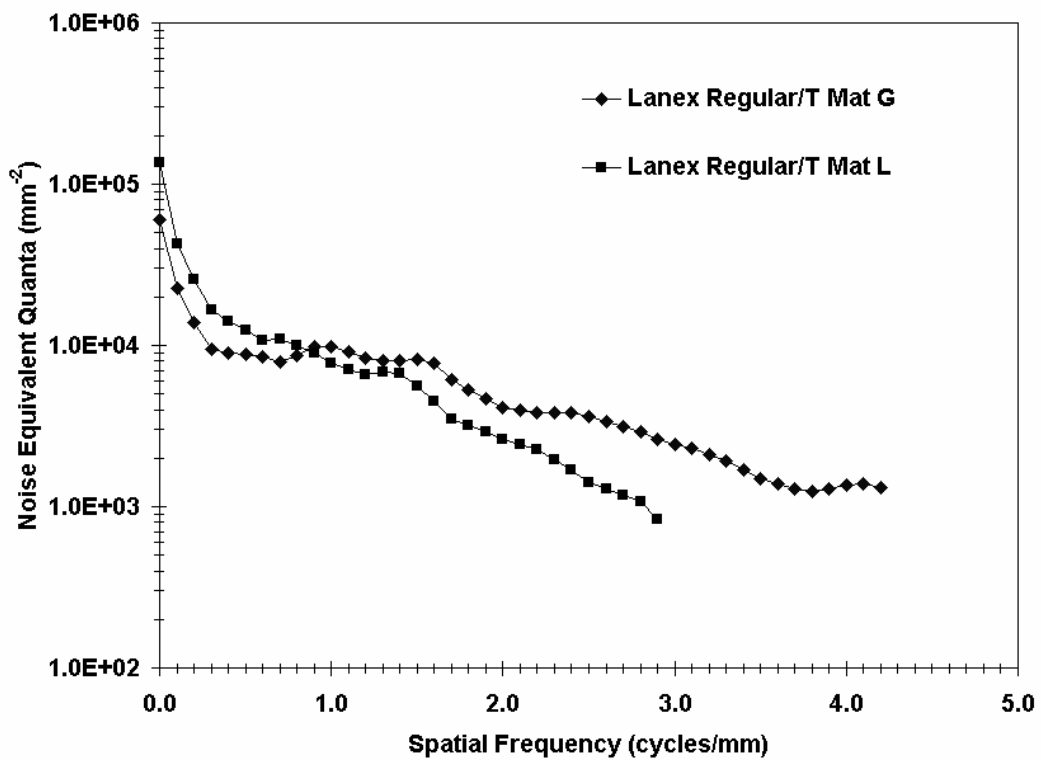
FIGURE 2. The NEQ of Lanex Regular/T Mat G and Lanex Regular/T Mat L.
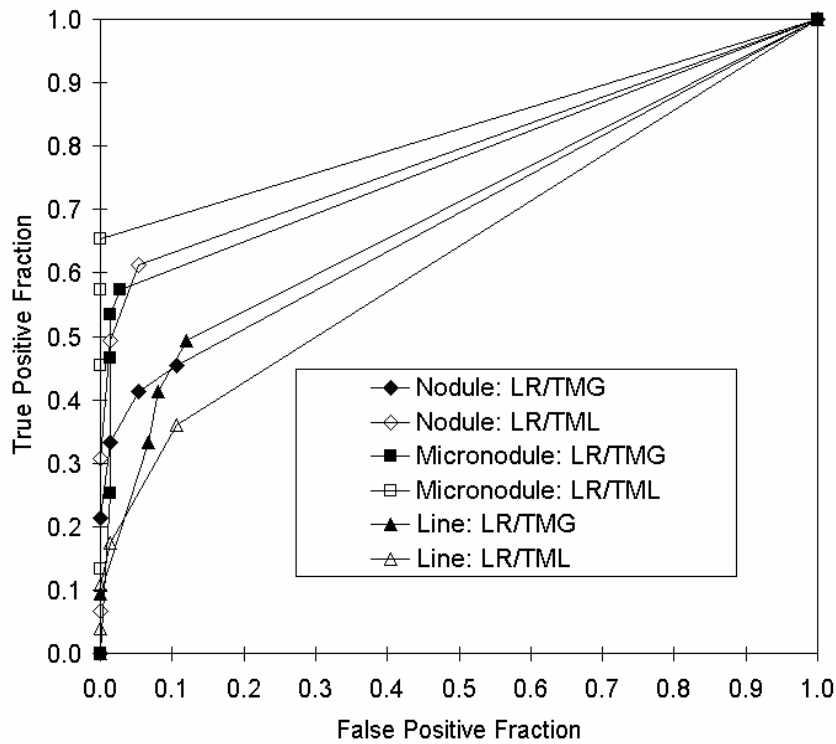
FIGURE 3. The ROC curves for detecting the nodules, lines, and micronodules using Lanex Regular/T Mat G (LR/TMG) and Lanex Regular/T Mat L (LR/TML) systems.

TABLE 1. Areas under the ROC curves.

Simulated lesion	Lanex Regular/T Mat G	Lanex Regular/T Mat L
Nodule	0.6908	0.7911
Micronodule	0.7748	0.8267
Line	0.6944	0.6342