Πειραματική και θεωρητική διερεύνηση αντικειμενικών χαρακτηριστικών ποιότητας εικόνας σε απεικονιστικά συστήματα (DOG, MTF, NPS, DQE)

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***Abstract*:**

Breast cancer is one of the most frequently diagnosed cancers among women. Several techniques have been developed to help in the early detection of breast cancer such as conventional and digital x-ray mammography, positron and single-photon emission mammography, etc. A key advantage in digital mammography is that images can be manipulated as simple computer image files. Thus non-dedicated commercially available image manipulation software can be employed to process and store the images. The image processing tools of the Photoshop (CS 2) software usually incorporate digital filters which may be used to reduce image noise, enhance contrast and increase spatial resolution. However, improving an image quality parameter may result in degradation of another. The aim of this work was to investigate the influence of three sharpening filters, named hereafter *sharpen, sharpen more and sharpen edges* on image resolution and noise. Image resolution was assessed by means of the Modulation Transfer Function (MTF).In conclusion it was found that the correct use of commercial non-dedicated software on digital mammograms may improve some aspects of image quality.

I.Introduction

One of the most recent advances in x-ray mammography is digital mammography. Digital mammography is similar to standard mammography in that x-rays are used to produce detailed images of the breast. Particularly, a digital mammography system differs from a standard system at: (a) the x-ray photon detection (digital detector instead of a radiographic cassette) and (b) image formation and display (analog-to-digital converters, image processors and dedicated monitors instead of radiographic films). An advantage of a digital image is the capability of software image post processing (application of software filters, etc.) which may help the radiologist to better visualize anatomical structures of the breast. Post processing techniques may be available in dedicated or general use available software packages [1,2,3,4].

The aim of the present study was to investigate the influence of three sharpening filters, incorporated in the commercial image processing tool of Photoshop Version 8 (Adobe Systems Incorporated, 345 Park Avenue, San Jose, California 95110, USA) on frequency domain image quality metrics such as the modulation transfer function (MTF) and noise. The three sharpening filters named 'sharpen', 'sharpen more' and 'sharpen edges'. To our knowledge such a study has not yet been carried out under digital mammographic exposure conditions [5,6,7].

II.Materials and methods

Image resolution was assessed by means of the Modulation Transfer Function (*MTF*). The modulation transfer function was experimentally determined by the Square Wave Response Function (*SWRF*) method. A Nuclear Associates resolution test pattern (typ-53, Nuclear Associates) containing Pb lines of various widths corresponding to various spatial frequencies (from 0.25 lp mm^{-1} to 10 lp mm^{-1}) was used to obtain pattern images. The *MTF* test pattern was irradiated by x-rays on a General Electric Senographe Essential

mammographic unit using a Mo/Mo x-ray spectrum at 28 *kVp* and 10*mAs*. The x-ray beam was additionally filtered by Perspex slab of 2.5*cm* thickness to simulate spectrum alteration. After the irradiation of the MTF test pattern the digital images were obtained in DICOM format. Softcopy display is performed on the GE Healthcare's Seno Advantage 2 Review Workstation. The raw DICOM images were converted to grayscale bitmap (.bmp) format. The three sharpening filters were then applied on the raw image data and three new images of the *MTF* test pattern were obtained [8,9,10].

MTFs were calculated from the digital images (both raw and filtered) density variations (digital *SWRF*). The latter were obtained across directions vertical with respect to the test pattern lines, employing Coltman's formula [11,12,13,14], which convert the square wave *CTF* to its equivalent sine wave *MTF*. *CTF* is given as [15]:

$$CTF(f) = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \qquad (1)$$

Where I_{max} is the local maxima and I_{min} is the local contrast minima for a given frequency f .

Given the *CTF*, the Coltman formula to determine the *MTF*, is

$$MTF(f) = \frac{\pi}{4}[C(f) + \frac{C(3f)}{3} - \frac{C(5f)}{5} + \frac{C(7f)}{7} + ...] \qquad (2)$$

Where *MTF(f)* is the sine wave *MTF*, C(f) is the bar target *CTF*. The latter gives the *MTF* as a function of *SWRF* [7,8].

The noise was estimated by means of the coefficient of variation (*Coef_var*) in an area of 100 pixels, where:

$$Coef\_\mathrm{var} = (stdev/mean\_value) \times 100 \qquad (3)$$

Where *stdev* is the standard deviation and *mean_value* is the mean value of image pixels, corresponding to the pixel values taken on the 100pixels area [16].

Pattern images were then analysed using Adobe PhotoShop professional Version 8 image analysis software. This version of Photoshop incorporates three basic sharpening filters named hereafter sharpen, sharpen more and sharpen edges.

The Sharpen filter is best used for minimal touch-ups in small areas. This single-step filter increases the contrast between all the pixels in the image or selection. Although this makes the image look sharper, it can add a grainy look to solid areas that aren't part of the edges.

The Sharpen More filter, a single-step filter that increases the contrast between pixels even more than the regular Sharpen filter. Also, this filter is best relegated to noncritical sharpening because it doesn't do a very good job of sharpening large areas.

The Sharpen Edges filter is a single-step filter that is superior to the Sharpen and Sharpen More filters because it concentrates its efforts on the edges of images, adding sharpness without making the image grainy or noisy [17,18,19].

III. Results and discussions

Fig.1 shows MTFs of the 'raw', 'processed' and 'filtered' image data. 'Processed' image data was the raw data subject to filtration by the mammographic unit workstation. The first point to notice is the low MTF values that the raw image data has. This can be explained due to the routine clinical practice conditions followed for this study, e.g. grid, bucky, compression plate and Perspex slabs in place. The processed image data shows a tendency to raise MTF above the spatial frequency of 2.7 *cycles/ mm*. In the low frequency range MTF appears decreased. The overall MTF curve of the processed image data have lower slope than the raw data which provides a small boost to the higher frequencies, giving the opportunity to increase the visibility of small objects in the final image.

An interest finding is that all the Photoshop sharpen filters had beneficial impact on the MTF. Fig.2 shows the MTFs obtained the 'raw' image data with the Photoshop filters. The Photoshop 'sharpen' filter follows a similar pattern with the one applied on the 'raw' image data. The 'Sharpen' filter holds smaller MTF values than the aforementioned filter for spatial frequencies up to 2.8 *cycles/ mm*. Beyond this point the 'Sharpen' filter increases more the MTF of 'raw' data, giving better resolution in this frequency range. Significant increase in the MTF was provided by the other two Photoshop filters. 'Sharpen more' filter gives increased MTF values compared to those of the raw data, above the spatial frequency of 1.4 *cycles/ mm,* and the 'sharpen edges' above the spatial frequency of 1.7 *cycles/ mm*. 'Sharpen more' filter follows a similar sigmoidal pattern MTF similar to that of the raw image data. It gives an important increase in the MTF in the medium to high

spatial frequency region (f=1.2 to f=7 mm^{-1}). 'Sharpen edges' filter shows a tendency to 'linearise' the 'sigmoidal' shape of the raw data MTF. It gives an impressive increase, beyond the spatial frequency of 2.9 *cycles/ mm*, compared to all the aforementioned filters and the raw image data. The superiority of the 'sharpen edges' filter is due to its specificity on the

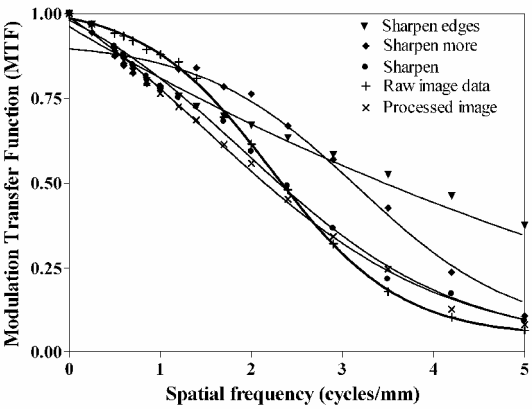

Fig.1: Comparison of the raw, processed image data and the filtered image MTFs.

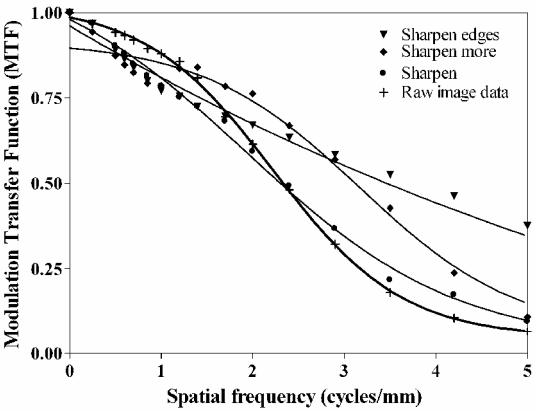

Fig.2: Comparison of the MTF of the raw image data with the ones obtained after the processing with the Photoshop filters.

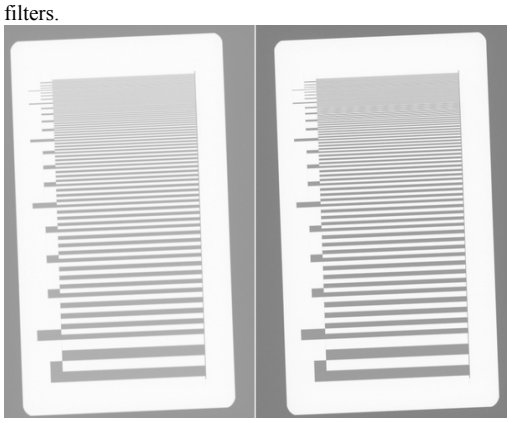

Fig.3: Image of the resolution test pattern (left: raw image data, right: processed with the Photoshop Sharpen edges filter).

edges of the digital images, adding sharpness without making the image grainy or noisy.

The noise was estimated by means of the coefficient of variation in an area of 100 pixels. 'Sharpen edges' filter exhibits a coefficient of variation of 0.864%. However, as expected, the image filtered by the 'sharpen more' filter appeared to be noisier corresponding to a coefficient of variation of 2.46%, as expected. The image filtered by the sharpen filter was poorer in resolution and moderate in noise with a coefficient of variation of 1.38%. So, the filter that exhibits lowest noise is the 'Sharpen edges' filter.

1. Conclusion

In the present study, the influence of three sharpening filters, incorporated in the widely available Photoshop image processing tool, on MTF and noise was investigated. It was found that MTF increased and best results were obtained for the 'sharpen edges' filter due to its specificity on the edges of the digital images, adding sharpness without making the image grainy or noisy exhibiting a coefficient of variation of 0.864%.

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References

[1] Pisano E. D., Radiology 214, 26–28 s2000d.

[2] Pisano and Yaffe, Radiology 2005, pp 353-362

[3] Yaffe M. J., Mainprize J. G., Vol. 3(4),(2004)

[4] Albagli, D., Hudspeth, H., Possin, G., Lee, J., Granfors, P., and Giambattista B. Proc. SPIE 5030, 553-563 (2003)

[5] R.M. Nishikawa and M.J. Yaffe Med. Phys. 17 (1990) 894

[6] R.M. Nishikawa and M.J. Yaffe Med. Phys. 16 (1989) 773.

[7]Norman B. Nill, Mitre technical report, July 2001

[8] Williams, M.B., Simoni, P.U., Smilowitz, L., Stanton, M., Phillips, W., Stewart, A.. Med. Phys. 26 (1999) 2273.

[9] P.C. Bunch, K.E. Huff and R.V. Metter, J.Opt. Soc.Am.A 4 (1987) 902.

[10] Kandarakis, I., Cavouras,. C., Nucl. Instr. Meth. Phys. Res. A. 417 (1998) 86.
[11] Kandarakis, I., Cavouras,. D., Radiat. Meas.39 (2005) 263
[12] Kandarakis, I., Cavouras,,. Appl. Phys. B. 72 (2001c) 877.
[13]Barnes, G.T., American Association of Physicists in Medicine, New York, (1979) 138.
[14]ICRU (International Commission on Radiological Units). Modulation transfer functions of screen–film systems, (1986) ICRU Report 41.
[15] E.P.Efstathopoulos, L. Costaridou, O. Kocsis, and G. Panayiotakis, The British Journal of Radiology, 74 (2001), 841–846
[16] Martin J. Yaffe, Aili K. Bloomquist, Gordon E. Mawdsley, Etta D. Pisano, R. Edward Hendrick, Laurie L. Fajardo, John M. Boone, Kalpana Kanal, Mahadevappa Mahesh, Richard C. FleischmanJoseph Och, Mark B. Williams, Daniel J. Beideck and Andrew D. A. Maidment, Med. Phys. 33 (3), March 2006
[17] Rogge, F., Bosmans, H., Willems, P. and Marchal, G.. Proc. SPIE 5030, 896–907 (2003).
[18]Shen, G. E., Mawdsley, S., Bloomquist, A. K., Mainprize, J. G. and Yaffe, M. J. In: Proceedings of the Workshop onIWDM, Bremen, Germany, June 2002, pp. 123–127 (2002)].
[19] H. Bosmans, A.-K. Carton F ,Radiation Protection Dosimetry (2005), Vol. 117, No. 1–3, pp. 120–130